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STOWAGE AND PRESENTATION OF PASSENGER PROTECTIVE BREATHING EQUIPMENT

Prepared for
Transportation Development Centre
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September, 1988

AVIATION PLANNING SERVICES LTD

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STOWAGE AND PRESENTATION OF PASSENGER PROTECTIVE BREATHING EQUIPMENT

BY

AVIATION PLANNING SERVICES LTD

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September, 1988

The contents of this report reflects the views of Aviation Planning Services Limited, Innotech Aviation, Behavioural Team and K. Owen and Associates, and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

Un sommaire en français de ce document est inclus avant la table des matières.

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17. Abstract

The objective of this study was to identify and define stowage and presentation concepts for passenger protective breathing equipment (PPBE) on turbine powered transport category aeroplanes in air carrier service.

After a review of equipment manufacturers, aircraft interiors, airworthiness requirements and draft PPBE equipment specifications, criteria for evaluation of stowage and presentation schemes were developed. Numerous schemes and scenarios were evaluated using a detailed cost analysis and several decision analysis techniques. Detailed sensitivity tests were also conducted. The evaluation clearly showed that automatic overhead PPBE systems were superior to the other concepts evaluated.

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17. Résumé

L'objectif de cette étude était d'identifier et de définir les possibilités de localisation et de présentation de protecteurs respiratoires à l'intention des passagers prenant place à bord d'avions turbopropulsés. Les critères d'évaluation utilisés dans cette étude ont été élaborés à partir de données obtenues des manufacturiers d'équipement et à la suite de l'analyse des intérieurs d'aéronefs, des exigences de navigabilité et des contraintes spécifiques au protecteur respiratoire.

De nombreux scénarios ont pu être évalués en se basant sur une analyse détaillée des coûts combinée à l'utilisation de différentes techniques d'analyse de décision et à une vérification de l'influence des paramètres à l'aide de tests de sensibilité.

L'analyse finale a nettement démontré la supériorité des systèmes de protecteurs respiratoires à présentation automatique localisés au plafond.

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E. EXECUTIVE SUMMARY

The objective of this study was to identify and define stowage and presentation concepts for passenger protective breathing equipment on turbine powered transport category aeroplanes in air carrier service. This study was commissioned by the Transportation Development Centre (TDC) of Transport Canada at the request of the Department's Airworthiness Branch.

The study methodology comprised eight basic work elements:

- An analysis of previously completed studies on the subject.
- A survey and analysis of current and proposed equipment manufacturers and their products.
- A summary of current and proposed airworthiness requirements.
- An analysis of how the equipment could be integrated with aircraft interiors.
- A definition of alternative stowage locations and presentation concepts.
- An analysis of capital and operating cost factors.
- An overall evaluation of the selected systems.
- An assessment of the applicability of the selected concepts.

The concept of providing respiratory protection to airline passengers to allow escape from burning aircraft was initiated in 1967. In 1983, the Ontario Research Foundation conducted a study to establish appropriate criteria for PPBE, to determine whether any available devices met these criteria, and if necessary, to recommend the direction of subsequent research and/or development. Further development was recommended primarily in the area of mask design. Following the 1985 Manchester incident in which 55 people died, once again there was significant interest in the life-saving potential of PPBE.

1. Background Data and Limitations

Of twenty PPBE manufacturers surveyed only four were actively pursuing PPBE development, although three more had prototypes under design.

The primary design goal faced by equipment manufacturers is to design a compact, lightweight unit which complies with the governing PPBE specifications. Since PPBE specifications were still at draft status as of March 1988, several manufacturers were uncommitted to PPBE design. In conclusion, the results of the survey are considered quite limited. Due to physical size, the ability to meet challenge atmosphere requirements, and development status, only two breathable gas based PPBE units were identified as likely candidates, both are still in the prototype development phase, and both are somewhat bulky and heavy. Whether these units will in fact satisfy forthcoming PPBE specifications affecting their use in transport category aircraft is presently unknown.

In order to prepare a cost analysis and to determine the feasibility of PPBE stowage within certain locations of the aircraft, a 'mean PPBE size envelope' was established, resulting in a mean PPBE volume of 1,376 cm^3 (84 cu in.). The weight of the PPBE unit including components, such as the polymer layers, the packaging, the oxygen supply system or filter system, and the enclosure was estimated to be 0.50 kg (1.1 lb) plus the weight of the stowage/presentation system.

Three types of PPBE systems are identified in the report, namely, a self-contained filter based PPBE system, a self-contained breathable gas supply, and a partially dependent breathable gas supply.

2. Airworthiness Requirements

The study addresses the relevant airworthiness regulations pertaining to PPBE including, Federal Aviation Regulation (FAR) 25, FAR 91, FAR 121, Joint Airworthiness Requirements (JAR) 25 and the Canadian Air Navigation Orders (ANO). Furthermore, three PPBE specifications are considered for this study. These are:

- CAA Specification No. 20 Issue 1 - Feb. 26, 1988.
- STPAe-CIN DTA/SG 64/RZ/MB/MF - 64.306 - Mar. 26, 1986.
- S.A.E. A-10 PPBE Draft Specification - Dec. 2, 1987.

The regulations considered in the report have been extracted from various design and operational requirements primarily common to North America but also recognized throughout the world. These deal exclusively with the installation of the equipment, and include considerations such as safety, accessibility, inspectability and serviceability.

Although specific airworthiness requirements will vary from country to country, certification of any PPBE will require that it meet either current and/or proposed regulations. Of particular importance is the requirement that PPBE be compatible with existing required equipment, and not interfere with, other mandatory equipment, (e.g. life vests, oxygen systems). In light of the results of the concept evaluation, which suggest that relatively complex automatic systems are rated most favourably, care must be taken during the equipment design phase to ensure that various mandatory systems are mutually compatible.

3. Concept Definitions and Limitations

To identify the permissible stowage and presentation PPBE locations, an ergonomic study was conducted of the reach envelopes available to seated passengers. Contour plots were generated in the X-Y and X-Z planes for increments along the Z and Y axes, respectively, for the five percentile woman body dimensions. The results were then superimposed on aircraft seating configurations to determine the points of intersection.

A survey of aircraft interiors was carried out in two stages. A preliminary interior configuration review was conducted: to establish the extent of diversity in the aircraft fleet considered in this study; to assist in the identification of possible stowage and presentation schemes; and to facilitate the identification of physical and functional constraints. The aircraft considered in the preliminary review included the B-747 and the L-1011. A final and more detailed interior configuration review was carried out to obtain data which would allow for detailed geometry review, and to obtain data for a cost analysis of the feasible stowage/presentation schemes. The survey of varying aircraft types indicated that the correlation with PPBE implementation schemes was weak; PPBE usability tended not to vary with aircraft types, but rather with the particular interior scheme or configuration chosen for any given aircraft model.

These detailed examinations led to the identification of ten feasible PPBE stowage/presentation concepts, which were then analysed in more detail. These include two automatic and eight self-help presentation schemes. For the two automatic presentation schemes, an overhead location and seat-back stowage was considered. Stowage locations considered for the self-help concepts included overhead locations hidden by a trim panel, seat-back (flush with seat), underseat (adjacent to the life vest stowage), headrest, armrest, meal-tray, seat-back (external to seat), and passenger carry-on.

4. Functional Constraints, Physical Constraints and Human Factors

The stowage/presentation schemes were then assessed with regard to functional constraints, including susceptibility to pilferage and damage, the likelihood of global donning in a limited time period, scenario exclusivity, the minimization of additional tasking to the cabin crew, and the minimization of both physical and functional interference with other passengers and existing aircraft systems. A summary of this assessment for each scheme is presented in Table S.1.

Physical constraints were also examined to ensure that suitable protection would be afforded to the unit itself, as well as the system. A summary of this evaluation for each scheme is displayed in Table S.2.

Finally, the scenarios were examined from the human-factors point-of-view, to assess the effects of passenger behaviour on stowage and presentation concepts. The positive and negative aspects are presented within the report. It is apparent that the automatic presentation schemes are far more desirable than self-help schemes, particularly when considering factors such as potential for human error which may lead to panic in an emergency situation. Furthermore the automatic schemes would also be more suitable for the "special population" who have a variety of limitations that will affect their ability to access and use a PPBE unit.

TABLE S.1 - FUNCTIONAL CONSTRAINT CONSIDERATIONS - SUMMARY

Stowage/Presentation Scheme	Functional Constraint Considerations
Overhead Automatic Presentation	- Satisfactory for combined smoke/hypoxia PPBE units. - Desirable W.R.T.(1) tampering, pilferage and damage. - Global emergency recognition and deployment time is minimized. - Passenger reach envelope requirements may be optimally satisfied. - Functional compatibility with existing system can be satisfied. - Minimizes crew tasking. - Minimizes global donning time. - Satisfactory W.R.T. post deployment constraint considerations.
Overhead Self-Help	- Unsatisfactory for combined smoke/ hypoxia PPBE units. - May be satisfactory W.R.T. tampering, pilferage and damage. - Global emergency recognition and deployment time is unknown. - Passenger reach envelope requirements may not be satisfied. - Functional compatibility with existing systems can be satisfied. - Will not minimize crew tasking. - Will not minimize global donning time. - Satisfactory W.R.T. post deployment constraint considerations.
Sidewall Self-Help	- Unsatisfactory for combined smoke/ hypoxia PPBE units. - Undesirable W.R.T. tampering, pilferage and damage. - Global emergency recognition and deployment time is unknown. - Passenger reach envelope requirements may not be satisfied. - Functional compatibility with existing systems can be satisfied. - Will not minimize crew tasking. - Will not minimize global donning time. - Satisfactory W.R.T. post deployment constraint considerations.

(1) W.R.T. = With respect to.

TABLE S.1 Continued

Seat-Back Automatic Presentation	- Satisfactory for combined smoke/hypoxia PPBE units. - Desirable W.R.T. tampering, pilferage and damage. - Global emergency recognition and deployment time is minimized. - Passenger reach envelope requirements may be easily satisfied. - Functional compatibility with existing systems can be satisfied. - Minimizes crew tasking. - Satisfactory W.R.T. post deployment constraint considerations.
Seat-Back Self-Help	- Unsatisfactory for combined smoke/ hypoxia PPBE units. - Undesirable W.R.T. tampering, pilferage and damage. - Global emergency recognition and deployment time is unknown. - Passengers reach envelope requirements may be easily satisfied. - Functional compatibility with existing systems can be satisfied. - Will not minimize crew tasking. - Will not minimize global donning time. - Satisfactory W.R.T. post deployment constraint considerations.
Seat Armrest and Meal-tray Self-Help	- Unsatisfactory for combined smoke/ hypoxia PPBE units. - Very undesirable W.R.T. tampering, pilferage and damage. Inadvertent damage probability may increase. - Global emergency recognition and deployment time is unknown. - Passenger reach envelope requirements may be satisfied. - Functional compatibility with existing systems can be satisfied. - Will not minimize crew tasking. - Will not minimize global donning time. - Undesirable post deployment constraint considerations.

TABLE S.1 Continued

Under-Seat Self-Help	- Unsatisfactory for combined smoke/ hypoxia PPBE units. - Undesirable W.R.T. tampering, pilferage and damage, inadvertent damage probability may increase. - Global emergency recognition and deployment time is not known. - Passenger reach envelopes requirements may be satisfied. - Functional compatibility with existing systems can be satisfied. - Will not minimize crew tasking. - Will not minimize global donning time. - Satisfactory post deployment constraint considerations.
Carry-On Self-Help	- Unsatisfactory for combined smoke/ hypoxia PPBE units. - Tampering, pilferage and damage are increased considerably. Inadvertent damage probability may increase considerably. - Global emergency recognition and deployment time is unknown. - Passenger reach envelopes requirements may be unsatisfactory. - Functional compatibility with existing systems can be satisfied. - Will not minimize crew tasking. - Will not minimize global donning time. - Satisfactory post deployment constraint considerations.

TABLE S.2 SUMMARY OF PHYSICAL CONSTRAINTS

Stowage/Presentation	Physical Constraints
Overhead Self-Help	- The scheme is not viable for most aircraft types and configurations since passenger reach envelopes are exceeded. - Extensive modifications are required to the overhead P.S.U. panels and existing overhead systems.
Overhead Automatic Presentation	- Replacement of existing overhead P.S.U. panels for most aircraft. - Modifications required to existing overhead systems. - Possible modification requirements to the baggage bin systems for some interior configurations. - Possible modification requirements to headliner/suspended ceiling for wide-body aircraft. - Removal of interior headliner/sidewall may be required to locate control wiring.
Seat-Back Automatic Presentation	- Existing hypoxia system preclude installation of a separate PPBE in some seat types. - Modifications to mealtray and other existing systems on the seat-back is required for some seat types. - Control wiring to seats is required. - For non-self contained PPBE, oxygen supply defaults to chemical cannister source. - Alternate stowage scheme required at discontinuous seating locations. - Protection from tampering and pilferage required for stowage design.

TABLE S.2 Continued

Seat-Back Self-Help	- Existing hypoxia system preclude installation a separate of PPBE for some seat types. - Modifications to mealtray and other existing systems on the seat-back required for some seat types. - For non-self contained PPBE, oxygen supply defaults to chemical cannister source. - Alternate stowage scheme required at discontinuous seating locations. - Protection from tampering and pilferage required for stowage design.
Under-Seat Self-Help	- Footrest modification required for some seat types. - Slight relocation of life vest stowage may be required. - Protection from tampering and pilferage required for stowage design.
Seat Pouch Self-Help	- Protection from tampering, pilferage, aircraft flight loads and damage required of stowage design, but notably very difficult to realize.
Sidewall Self-Help	- Reach envelopes are exceeded for three abreast seating, and non-optimal location for two abreast seating. - Stowage space availability is limited.
Passenger Carry-On	- Acceptable stowage locations are limited to person, magazine pouch of facing seat, resulting in severe functional constraints. - No stowage protection afforded from tampering, pilferage, aircraft flight loads or damage.
Seat Armrest and Mealtray Self-Help	- Severe space limitations for many seat types. - Relocation of existing armrest systems may be required. - Protection from tampering, pilferage and damage required, but, notably difficult to realize.

5. Cost Analysis

The cost for implementation of any given scheme was found to be principally influenced by the existing passenger service unit (PSU) panel, baggage bin geometry and seat characteristics. The analysis includes costs such as labor required to modify existing systems (seats, PSU panels, baggage bins), material (wiring, sensors, fabrics), and engineering support. Labor rates used for the analysis ranged from $48 to $58. The unit cost of a PPBE has been estimated at C$300. On that basis, the implementation costs per seat, including an allowance for 10% redundancy, ranged from about $500 for a simple carry-on system, to about $2,500 for a complex overhead automatic presentation system. Implementation costs were defined to include all non-recurring cost elements.

Recurring costs assessed in this analysis include pilferage, weight penalty, carrying costs, inspection and maintenance and servicing. Annual recurring costs were estimated to vary between $150 and $200 per seat for all systems, without including any interest or capital charges, or depreciation. Depending on individual airline's accounting system, these could add an additional $50-$250 annual cost. Based on 3,000 hours annual aircraft utilization, annual costs would range from about 8 - 13 cents per seat per flight hour.

6. System Evaluation

In order to evaluate the numerous stowage/presentation schemes, based on the functional and physical constraints, and costs, two independent sets (large and small aircraft) of Binary Decision Analyses were conducted. In addition, eight sensitivity tests to the Binary Analysis, and a cost sensitivity was developed.

Binary decision theory was used to evaluate all concepts against five critical mutually-exclusive criteria:

- Recognition and Access Time.
- Usability and Inspectability.
- Crew Tasking.
- Installation Costs.
- Recurring Costs.

The two automatic systems (overhead and seatback) ranked first and second by a clear margin, despite being the most expensive. The carry-on scheme ranked last, despite being the least expensive. The various self-help concepts ranked in between the two extremes.

A series of sensitivity tests was run to determine whether or not the results varied with reasonable changes to the inputs. Eleven tests were computed, and the overhead automatic system ranked first in all of them. The automatic seat-back system ranked second in 9 of 11 trials, while the self-help seat pocket system ranked no worse than third in 10 of 11 trials.

7. Applicability of Selected Concepts

Short and long term PPBE implementation schemes were examined. Schemes which have low costs, are readily recognized, and do not have a requirement for speciality manufacturing would likely be implemented in the short term. These would include the carry-on, the underseat stowage or the seat-back pouch self-help schemes.

In the long term, smoke/hypoxia hybrid PPBE systems, if available, would likely be implemented in new aircraft.

8. Conclusion

Based on the review of equipment manufacturers, aircraft interiors, airworthiness requirements and draft PPBE equipment specifications, criteria for evaluation of stowage and presentation schemes were developed. Numerous schemes and scenarios were evaluated using a detailed cost analysis and several decision analysis techniques. Detailed sensitivity tests were also conducted. The evaluation clearly showed that automatic overhead PPBE systems were superior to the other concepts evaluated.

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SOMMAIRE

Le but de cette étude était d'identifier et de définir les possibilités de localisation et de présentation de protecteurs respiratoires à l'intention des passagers prenant place à bord des avions turbopropulsés utilisés par les lignes aériennes. Cette étude a été commandée par le Centre de développement des transports (Transportation Development Centre) de Transport Canada à la demande de sa Division de navigabilité aérienne.

La méthodologie employée dans cette étude comprenait huit éléments de base:

- l'analyse des études préalablement complétées sur le sujet;
- l'étude des différents manufacturiers ainsi que des équipements disponibles et en voie de développement;
- le résumé des exigences de navigabilité actuelles et proposées;
- l'analyse des moyens d'intégration de l'équipement à l'intérieur des aéronefs;
- la définition d'alternatives quant à la localisation et à la présentation de l'équipement;
- l'analyse des coûts en capital et des frais d'exploitation;
- l'évaluation globale des systèmes choisis;
- l'évaluation de l'applicabilité des systèmes choisis.

L'idée de fournir une protection respiratoire adéquate afin de faciliter l'évacuation des passagers d'un aéronef en feu fût lancée en 1967. En 1983, la Fondation de recherche de l'Ontario a réalisé une étude afin d'établir des critères appropriés pour le protecteur respiratoire et déterminer si certains des dispositifs actuellement disponibles répondaient à ces critères. Aussi, elle se proposait de faire des recommandations relatives à des avenues de recherche et/ou de développement. Il a été recommandé de poursuivre des activités de développement dans le domaine de la conception des modèles de protecteurs. A la suite de l'accident survenu à Manchester en 1985 au cours duquel 55 personnes perdirent la vie,

le potentiel du protecteur respiratoire comme facteur de survie a suscité un intérêt énorme.

1. Informations générales et limitations

Des vingt manufacturiers de protecteurs respiratoires approchés, quatre seulement étaient engagés activement dans le développement et la recherche, bien que trois autres avaient en main des études préliminaires de prototypes.

Le principal défi pour les manufacturiers est de concevoir un dispositif compact, léger et conforme aux spécifications régissant les protecteurs respiratoires. Commes ces spécifications étaient encore à l'état d'ébauche au mois de mars 1988, plusieurs manufacturiers ne s'étaient pas encore engagés dans l'étape de la conception. Les résultats de cette partie de l'étude sont par conséquent très limités. Parmi tous les candidats possibles, seulement deux modèles de protecteurs, avec apport de gaz respirable, ont été retenus et ce, même s'ils sont encore à l'état de prototype et qu'ils sont lourds et encombrants. En fait, on ignore présentement si ces modèles sauront satisfaire la future législation relative à leur utilisation dans les aéronefs. Les autres ont été éliminés soit à cause de problèmes de dimension, d'inaptitude à protéger des contaminants ou de l'état embryonnaire de leur développement.

Afin de préparer une analyse de coût et de déterminer la faisabilité de la localisation du protecteur à l'intérieur de certaines parties de l'aéronef, une "enveloppe dimensionnelle moyenne du protecteur respiratoire" a été estimée, donnant un volume moyen de 1,376 cm^3 (80 po. cu.). Le poids du protecteur respiratoire et de ses diverses composantes (couches de polymère, empaquetage, système d'alimentation en oxygène, système de filtration et enceinte) a été estimé à 0.50 kg (1.1 lb). A cela il faut ajouter le poids du dispositif de localisation/présentation.

Trois types de protecteurs respiratoires sont retenus dans ce rapport: un système de protecteur respiratoire indépendant à base de filtre, un système d'alimentation en gaz respirable également indépendant et un système d'alimentation en gaz respirable partiellement dépendant.

2. Exigences de navigabilité

L'étude tient compte des règlements de navigabilité suivants concernant le protecteur respiratoire: Federal Aviation Regulation (FAR) 25, FAR 91, FAR 121, Joint Airworthiness Requirements (FAR) 25 et des Ordonnances de la Navigation Aérienne (Canada). De plus, trois séries de spécifications de protecteurs respiratoires sont prises en considération dans cette étude. Elles sont:

- CAA Specification No. 201 Issue 1 - 26 février 1988;
- STPAe-CIN DTA/SG 64/RZ/MB/MF - 64.306 - 26 mars 1986;
- S.A.E. A-10 PPBE Draft Specification - 2 décembre 1987.

Les règlements dont ce rapport tient compte sont extraits des diverses exigences gouvernementales tant conceptuelles qu'opérationnelles en usage surtout en Amérique du Nord, mais aussi reconnues à travers le monde. Ces règlements concernent exclusivement l'installation de l'équipement et tiennent compte de facteurs tels que la sécurité, l'accessibilité, la facilité d'inspection et la fiabilité.

Bien que certaines exigences de navigabilité varient d'un pays à l'autre, un protecteur respiratoire devra satisfaire les règlements actuels et/ou proposés afin d'être certifiable. Il est primordial que le protecteur respiratoire soit compatible avec tout équipement déjà existant et n'entrave pas le fonctionnement d'autres dispositifs obligatoires tels que gilets de sauvetage, systèmes d'apport d'oxygène, etc. L'analyse critique des résultats de l'évaluation des différentes possibilités laisse supposer qu'en général les systèmes automatiques relativement complexes se classent en tête de liste, et l'on devra apporter un soin particulier à la conception de l'appareil pour s'assurer que les diverses installations soient mutuellement compatibles.

3. Définitions et limitations des concepts

En vue de trouver des emplacements acceptables pour la localisation et la présentation du protecteur respiratoire, une étude ergonomique a été réalisée pour déterminer le volume spatial accessible aux passagers assis. Des tracés-profils ont été produits sur les plans X-Y et X-Z pour des accroissements le long des axes Z et Y respectivement, et ce pour les dimensions corporelles correspondant au cinquième percentile femmes. Les résultats furent ensuite superposés sur des croquis représentant différentes configurations de sièges d'avions pour déterminer les points d'intersection.

L'étude des intérieurs d'aéronefs a été menée en deux étapes. Une révision préliminaire de la configuration intérieure a d'abord été effectuée pour établir l'importance de la diversité dans la flotte d'aéronefs à l'étude, pour identifier ensuite les possibilités de localisation et présentation et enfin pour faciliter l'identification des contraintes physiques et fonctionnelles. La liste des aéronefs soumis à l'examen préliminaire comprenait le B-747 et le L-1011. Le relevé des différents types d'aéronefs démontra que les possibilités d'installation des protecteurs variaient beaucoup d'une configuration de cabine à l'autre. Une configuration de cabine type a ensuite été élaborée afin d'obtenir non seulement des données qui permettraient un examen géométrique complet, mais aussi d'autres données permettant une analyse des coûts.

Ces examens détaillés menèrent à l'identification de dix concepts possibles de localisation/présentation du protecteur respiratoire, lesquels furent par la suite analysés avec plus de précision. Il s'agissait de deux concepts de présentation automatique et de huit possibilités de présentation de type libre-accès. Dans le cas des deux projets de présentation automatique, des emplacements au plafond et au dossier furent retenus pour la localisation. Les emplacements envisagés pour les concepts libre-accès se situaient au-dessus de la tête du passager (cachés par le panneau décoratif), dans le dossier (au ras du siège), sous le fauteuil (contigu à l'espace de rangement des gilets de sauvetage), dans l'appuie-tête, dans l'accoudoir, intégré à la tablette, au dossier (à l'extérieur du fauteuil), ou faisant partie des bagages à main du passager.

4. Contraintes fonctionnelles, contraintes physiques et facteurs humains

Les différents concepts de localisation et de présentation ont ensuite été évalués en fonction de contraintes fonctionnelles telles que la possibilité de vol ou de bris, l'éventualité d'avoir à revêtir le protecteur respiratoire à l'intérieur d'un laps de temps limité, le respect du scénario, la minimisation de la tâche supplémentaire de l'équipage, et l'interférence autant physique que fonctionnelle des autres passagers et des systèmes déjà existants dans l'aéronef. Un résumé de cette évaluation pour chaque concept est présenté au Tableau S-1.

Les contraintes physiques ont également été examinées afin d'accorder une protection adéquate au dispositif lui-même aussi bien qu'au système de présentation. Un résumé de cette évaluation pour chaque concept est présenté au Tableau S.2.

TABLEAU S.1 - CONTRAINTES FONCTIONNELLES PRISES EN CONSIDERATION

Présentation automatique/Plafond

. Satisfaisant pour les protecteur respiratoires contre fumée et hypoxie combinés.
. Souhaitable pour prévenir le sabotage, le vol et le bris.
. Le temps total de repérage et de déploiement en cas d'urgence est réduit au minimum.
. L'accessibilité à l'appareil est optimale.
. Bonne compatibilité fonctionnelle avec le système existant.
. Minimise la tâche de l'équipage.
. Minimise le temps requis pour revêtir l'appareil.
. Satisfaisant du point de vue de contraintes après-déploiement.

Libre-accès/Plafond

. Non satisfaisant pour les protecteurs respiratoires contre fumée et hypoxie combinés.
. Peut être souhaitable pour prévenir le sabotage, le vol et le bris.
. Le temps total de repérage et de déploiement en cas d'urgence est inconnu.
. L'accessibilité à l'appareil peut être insuffisante.
. Bonne compatibilité fonctionnelle avec les systèmes existants.
. Ne minimisera pas la tâche de l'équipage.
. Ne minimisera pas le temps requis pour revêtir l'appareil.
. Satisfaisant du point de vue de contraintes après-déploiement.

Libre-accès/Mur latéral

. Non satisfaisant pour les protecteurs respiratoires contre fumée et hypoxie combinés.
. Non souhaitable pour prévenir le sabotage, le vol et le bris.
. Le temps total de repérage et de déploiement en cas d'urgence est inconnu.
. L'accessibilité à l'appareil risque d'être insuffisante.
. Bonne compatibilité fonctionnelle avec les systèmes existants.
. Ne minimisera pas la tâche de l'équipage.
. Ne minimisera pas le temps requis pour revêtir l'appareil.
. Satisfaisant du point de vue de contraintes après-déploiement.

Présentation automatique/Dossier

. Satisfaisant pour les protecteurs respiratoires contre fumée et hypoxie combinés.
. Souhaitable pour prévenir le sabotage, le vol et le bris.
. Le temps total de repérage et de déploiement en cas d'urgence est réduit au minimum.
. L'accessibilité à l'appareil peut être amplement suffisante.
. Bonne compatibilité fonctionnelle avec les système existants.
. Minimise la tâche de l'équipage.
. Satisfaisant du point de vue de contraintes après-déploiement.

TABLEAU S.1 - (suite)

Libre-accès/Dossier

. Non satisfaisant pour les protecteurs respiratoires contre fumée et hypoxie combinés.
. Non souhaitable pour prévenir le sabotage, le vol et le bris.
. Le temps total de repérage et de déploiement en cas d'urgence est inconnu.
. L'accessibilité à l'appareil peut être amplement suffisante.
. Bonne compatibilité fonctionnelle avec les système existants.
. Ne minimisera pas la tâche de l'équipage.
. Ne minimisera pas le temps requis pour revêtir l'appareil.
. Satisfaisant du point de vue de contraintes aprés-déploiement.

Libre-accès/Accoudoir et tablette

. Non satisfaisant pour les protecteurs respiratoires contre fumée et hypoxie combinés.
. Très peu souhaitable pour prévenir le sabotage, le vol et le bris. La probabilité de bris par inadvertance est augmenter.
. Le temps total de repérage et de déploiement en cas d'urgence reste inconnu.
. L'accessibilité à l'appareil peut être suffisante.
. Bonne compatibilité fonctionnelle avec les systèmes existants.
. Ne minimisera pas le tâche de l'équipage.
. Ne minimisera pas le temps requis pour revêtir l'appareil.
. Non souhaitable du point de vue de contraintes après-déploiement.

Libre-accès/Sous le fauteuil

. Non satisfaisant pour les protecteurs respiratoires contre fumée et hypoxie combinés.
. Peu souhaitable pour prévenir le sabotage, le vol et le bris. La probabilité de bris par inadvertance est augmenter.
. Le temps total de repérage et de déploiement en cas d'urgence reste inconnu.
. L'accessibilité à l'appareil peut être suffisante.
. Bonne compatibilité fonctionnelle avec les systèmes existants.
. Ne minimisera pas la tâche de l'équipage.
. Ne minimisera pas le temps requis pour revêtir l'appareil.
. Satisfaisant du point de vue de contraintes après-déploiement.

Libre-accès/Bagages à main

. Non satisfaisant pour les protecteurs respiratoires contre fumée et hypoxie combinés.
. Les possibilités de sabotage, de vol et de bris augmentent considérablement, ainsi que le bris par inadvertance.
. Le temps total de repérage et de déploiement en cas d'urgence reste inconnu.
. L'accessibilité à l'appareil peut être insuffisante.
. Bonne compatibilité fonctionnelle avec les système existants.
. Ne minimisera pas la tâche de l'équipage.
. Ne minimisera pas le temps requis pour revêtir l'appareil.
. Satisfaisant du point de vue de contraintes après-déploiement.

TABLEAU S.2 - RESUME DES CONTRAINTES PHYSIQUES

Libre-accès/Plafond

. Le concept ne convient pas à la plupart des types d'aéronef et des configurations de cabine puisque le volume spatial accessible au passager est excédé.

. Des modifications considérables devront être apportées aux panneaux supérieurs de service aux passagers et aux systèmes déjà en place au plafond.

Présentation automatique/Plafond

. Remplacement des panneaux supérieurs de service aux passagers déjà existants.

. Nécessité de modifier les systèmes déjà en place au plafond.

. Des modifications aux compartiments à bagages pourraient s'avérer nécessaires dans certaines configurations de cabine.

. Nécessité de modifier le plafond suspendu dans la plupart des gros porteurs.

. L'enlèvement du mur latéral intérieur pourrait s'avérer nécessaire afin de localiser le câblage de contrôle.

Présentation automatique/Dossier

. Le système hypoxie existant exclut la possibilité d'installer un protecteur respiratoire indépendant sur certains types de fauteuils.

. Il serait nécessaire d'apporter des modifications aux tablettes et aux autres systèmes existants sur certains dossiers.

. L'installation du câblage de contrôle dans les fauteuils devient nécessaire.

. Pour les protecteurs non indépendants, l'alimentation en oxygène provient d'une cartouche chimique.

. Il est nécessaire de prévoir un plan de localisation alternatif aux endroits où les rangées de fauteuils sont discontinues.

. Des mesures préventives contre le sabotage et le vol doivent être envisagées lors de la conception de l'espace de rangement.

Libre-accès/Dossier

. Le système hypoxie existant exclut la possibilité d'installer un protecteur respiratoire indépendant sur certains types de fauteuils.

. Modifications à apporter à la tablette et aux autres systèmes existants sur le dossier de certains types de fauteuils.

. Pour les protecteurs non indépendants, l'alimentation en oxygène provient d'une cartouche chimique.

. Il est nécessaire de prévoir un plan de localisation alternatif aux endroits où les rangées de fauteuils s'arrêtent.

. Des mesures préventives contre le sabotage et le vol doivent être envisagées lors de la conception de l'espace de rangement.

TABLEAU 8.2 - (suite)

Libre-accès/Sous le fauteuil

. Modifications à apporter au repose-pieds sur certains types de fauteuils.

. Une légère relocalisation de l'espace de rangement du gilet de sauvetage peut être nécessaire.

. Des mesures préventives contre le sabotage et le vol doivent être envisagées lors de la conception de l'espace de rangement.

Libre-accès/Pochette du dossier

. Des mesures préventives contre le sabotage, le vol, la turbulence et le bris doivent être envisagées lors de la conception du rangement résultant en un niveau de difficulté pratiquement insurmontable.

Libre-accès/Mur latéral

. Le volume spatial accessible au passager est excédé pour les groupes de trois sièges de front et demeure minimal pour les groupes de deux sièges.

. Peu de possibilité pour la localisation.

Bagages à main/Passagers

. Espace de rangement limité à la personne elle-même et à la pochette du fauteuil de devant causant ainsi de graves contraintes fonctionnelles.

. Aucune protection contre le sabotage, le vol, la turbulence ou le bris.

Livre-Service/Accoudoir et tablette

. Fortes restrictions d'espace disponible pour tous les types de fauteuils.

. Nécessité de relocaliser le système d'accoudoir.

. Protection nécessaire contre le sabotage, le vol et le bris, mais particulièrement difficile à réaliser.

Finalement, les scénarios ont été examinés du point de vue des comportements humains, afin d'évaluer les effets du comportement des passagers sur les concepts de localisation et de présentation. Le rapport présente non seulement les aspects positifs mais aussi les aspects négatifs. Il est évident que les concepts de présentation automatique sont plus souhaitables que les concepts libre-accès, surtout si l'on prend en considération des facteurs comme celui de la possibilité d'une erreur humaine qui pourrait semer la panique lors d'une situation d'urgence. De plus, le concept automatique conviendrait mieux aux personnes souffrant d'handicaps physiques les empêchant d'avoir un accès facile au protecteur respiratoire.

5. Analyse des coûts

Les éléments qui ont le plus influencé le coût de mise en oeuvre de l'un ou l'autre des concepts évalués sont: le panneau existant du module de service aux passagers, la géométrie du compartiment à bagages et les caractéristiques des fauteuils. L'analyse comprend les coûts d'ingénierie et ceux de la main d'oeuvre nécessaire pour modifier les systèmes existants (fauteuils, panneaux du module de service aux passagers, compartiments à bagages, les matériaux (câblage, détecteurs, tissus)). Le coût horaire de la main-d'oeuvre utilisée pour les fins de l'analyse varient de 48 $ à 58 $. Le coût du protecteur respiratoire lui-même a été estimé à environ 300 $. Ainsi, le coût de revient par fauteuil-unité de la mise en place de l'appareil choisi (incluant une allocation de redondance de 10%) variait de 500 $ pour un système simple de bagages à main à 2 500 $ pour un système de présentation automatique au plafond. Les coûts de mise en place ont été établis de façon à inclure toutes les dépenses extraordinaires.

Les dépenses périodiques estimées dans cette analyse incluent celles résultant du vol, les coûts supplémentaires pour l'excédant de poids, les coûts de transport, l'inspection et l'entretien. Les dépenses périodiques annuelles estimées varieraient de 150 $ à 200 $ par fauteuil-unité pour tous les systèmes sans inclure les frais d'intérêt, de capital ou de dépréciation. Ces dernières dépenses pourraient augmenter le coût annuel de 50 $ à 250 $ par unité selon le système de comptabilité adopté par chaque compagnie aérienne. En se basant sur une utilisation annuelle de 3000 heures par aéronef, les coûts annuels varieraient de 8 à 13 cents par fauteuil-unité, par heure de vol.

6. Evaluation du système

Afin d'évaluer les nombreux concepts localisation/présentation sur la base de contraintes fonctionnelles et physiques et des coûts, deux séries d'analyses indépendantes (gros et petit aéronef) furent effectuées par la technique de décision binaire. De plus, 8 tests de sensibilité des dites analyses ainsi qu'une analyse de la variation des coûts en fonction des différents paramètres ont été élaborés. A partir de la technique des décisions binaires, tous les concepts ont été évalués d'après cinq critères qui s'excluent mutuellement.

- Repérage et temps d'accès
- Commodité et facilité d'inspection
- Tâche de l'équipage
- Coût d'installation
- Dépenses périodiques

Les deux systèmes automatiques (au plafond et dans le dossier) ont été de loin classés premier et deuxième, bien qu'ils soient les plus coûteux. Le concept du bagage à main s'est classé bon dernier même s'il est le moins coûteux. Les différents concepts libre-accès se classèrent à mi-chemin entre les deux extrêmes.

Une série de tests de sensibilité ont été effectués afin de déterminer si les résultats pouvaient varier dans l'éventualité de changements apportés aux paramètres. Le système de présentation automatique/plafond s'est classé premier sur onze tests effectués. Le système automatique/dossier s'est classé deuxième dans 9 tests sur 11, pendant que le système libre-accès/pochette du dossier s'est classé bon troisième 10 tests sur 11.

7. Faisabilité des concepts choisis

La possibilité de mise en oeuvre du protecteur respiratoire à court et à long terme a été examinée. Les concepts à coût minime qui n'exigent pas de fabrication spécialisée sont susceptibles d'être considérés pour une implantation à court terme. Ils comprennent les concepts de bagages à main, rangement sous le fauteuil ou libre-accès/pochette du dossier. A long terme, les systèmes protecteurs respiratoires hybrides fumée/hypoxie, s'ils étaient disponibles, seraient probablement implantés dans les aéronefs neufs seulement.

8. Conclusion

Les critères d'évaluation utilisés dans cette étude ont été élaborés à partir de données obtenues des manufacturiers d'équipement et à la suite de l'analyse des intérieurs d'aéronefs, des exigences de navigabilité et des contraintes spécifiques au protecteur respiratoire proposé.

De nombreux scénarios ont pu être évalués en se basant sur une analyse détaillée des coûts combinée à l'utilisation de plusieurs différentes techniques d'analyse de décision et à une vérification précise de l'influence des paramètres par des tests de sensibilité.

L'analyse finale a nettement démontré la supériorité des systèmes de protecteurs respiratoires à présentation automatique localisé au plafond.

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1. INTRODUCTION

In recent years, Canada has joined with several other nations to develop specifications for the development and installation of passenger protective breathing equipment (PPBE) on aircraft. Beginning in the fall of 1986 representatives from Canada, the United States of America (U.S.A.), the United Kingdom (UK) and France undertook to evaluate the life saving potential of PPBE.

As part of its commitment to this multinational effort, the Airworthiness Branch of Transport Canada has requested the Transportation Development Centre (TDC) to undertake a study on stowage and presentation concepts for such equipment. TDC, in turn, awarded a contract to Aviation Planning Services Ltd. (APS) to manage and coordinate the work effort of several firms, including Innotech Aviation, Behavioural Team, and Ken Owen and Associates. This report presents the results of that study.

1.1 Study Objectives

The objective of this study was to identify and define stowage and presentation concepts for passenger protective breathing equipment on turbine-powered transport category aeroplanes in air carrier service.

1.2 Methodology

The study methodology in general followed the presentation format of this report, and covered eight basic work elements:

- An analysis of previously completed studies on the subject.
- A survey of current and proposed equipment manufacturers.

- A summary of current and proposed airworthiness requirements.
- An analysis of how the equipment could be integrated with aircraft interiors.
- A definition of alternative stowage locations and presentation concepts.
- An analysis of capital and operating cost factors.
- An overall evaluation of the selected systems.
- An assessment of the applicability of the selected concepts.

The above work elements were completed according to the general criteria defined by the terms of reference which, for convenience, are restated in Table 1.1.

Wherever possible, these criteria were respected. In several cases, however, it was not clear that they could be met by any system (eg. the criteria requiring "effective use ... within ten seconds"). In such cases, the study attempted to optimize these criteria as much as possible, without losing sight of the pragmatic overall objective, namely the identification and definition of practical PPBE concepts. The criteria are discussed in the main body of the report.

1.3 Background

The concept of providing respiratory protection to airline passengers to allow escape from burning aircraft is not new. The idea was studied as early as 1967. In 1969, in fact, the U.S. Federal Aviation Administration (FAA) issued Notice of Proposed Rule Making (NPRM) 69-2 which proposed the use of smoke hoods to provide airline passengers with respiratory

TABLE 1.1 - STUDY CRITERIA

Aeroplanes:
In developing the stowage/presentation concepts the contractor will consider large (over 5,700 kg M.T.O.W.) turbine powered transport category aeroplanes, having a passenger seating capacity of more than 30, currently in air carrier service. Both old and new, narrow and wide bodied, design must be addressed. Typical interior configurations for each type must be investigated to establish the range of PPBE stowage installations which may be necessary. Amongst the variables which may impact this range are:

Seats
- Type - manufacturer, model.
- Orientation - forward or aft facing.
- Pitch - high or low density.
- Location - adjacent to exits, galleys or bulkheads.
- Oxygen - integral oxygen chemical generators.

Interior design
- Passenger service unit location, cabin ceiling height, number of seats abreast, number of aisles.

Types of PPBE:
At least the following types of PPBE must be considered:

i) Self contained breathable gas units
ii) Self contained filtration units
iii) Combined smoke/hypoxia protection systems

Stowage/Presentation Concepts:
Two basic concepts must be considered:

i) Passenger self-help where access to the equipment is controlled by the passenger.
ii) Automatic presentation where access to the equipment is controlled by the crew members. A back-up manual access capability should also be considered for these installations.

TABLE 1.1 Continued

Performance: The stowage/presentation must be such that the PPBE, as installed, will be capable of being put into effective use by the wearer within 10 seconds of its need being recognized. It is anticipated that the major portion of this 10 second interval may be required for donning the device, leaving a relatively short interval for actually gaining access.
Stowage Enclosure: The enclosure should be capable of providing a hermetically sealed environment for PPBE, which in the case of self-help installations should not require more than a single action and no undue dexterity or force to gain access to the PPBE.
Location: The location of the stowage compartment must be obvious and must be such as to be readily accessible to passenger when seated and when standing in the seat row. Access should also be possible by passengers standing in the adjacent aisle area. However, the performance criteria may be conservative in this last instance.
Number: PPBE must be provided for each passenger cabin occupant, including cabin attendants, and considerations will be given to providing additional units for use by infants/children sitting on the laps of adults. The number of additional units should be approximately 10% of those required for passengers, should be evenly distributed throughout the passenger compartment and must be accessible when standing in the aisle.
Damage: The location and design of the stowage should be such as to minimize the possibility of damage from passengers gaining access or leaving their seats, using overhead and underseat stowage compartments and features such as meal tray tables, seat-back pockets, seat-arm audio and light controls, ashtrays and reclining mechanisms, underseat legroom, etc,.
Pilferage: The stowage concepts presented should be such as to discourage pilferage of PPBE units.

TABLE 1.1 Continued

Inspection: Provisions must be included to readily determine the integrity of the stowage hermetic seal and/or condition of the breathable gas supply on PPBE so equipped. The stowage must be such as to provide a clear indication to the cabin attendants if the PPBE has been tampered with. This indication should be such as to attract the cabin attendants' attention without the necessity of a unit inspection.
Size: The stowage/presentation concepts presented must cater for a range of equipment sizes. The contractor should consult a number of equipment manufactureres to establish the likely range which should be provided.
Weight: PPBE weighing up to 1 kg must be considered.
Regulations: The contractor should consider all current relevant FAR 25 regulations, as well as other relevant operating regulations, when developing the stowage presentation concepts. A partial list of applicable regulations is attached to the work statement for the guidance of the contractor.

protection in the case of fire. However, the notice was withdrawn on the grounds that use of smoke hoods could delay emergency evacuation.

Following the Cincinnati DC-9 accident in 1983 the Ontario Research Foundation, on behalf of Transport Canada, conducted a study to establish appropriate criteria for PPBE, to determine whether any available devices met these criteria, and if necessary, to recommend the direction of subsequent research and/or development. After a review of existing standards and regulations, criteria and test protocols were developed for: edge leakage, smoke and toxic gas penetration, conditions of inhaled air, ease of donning, vision and communication and breathing resistance. Six candidate masks were evaluated using the test protocol. Further development was recommended in the areas of vision and communication, breathing resistance, particulate edge leakage, resistance to flame and selection of test subjects.(1)

The occurrence, on take-off, of a major fuel fire on a Boeing 737 in Manchester, England in 1985, in which 55 people died, has revived significant international interest in the possible life-saving potential of PPBE. Studies by the United States to determine whether the mandatory carriage of PPBE is likely to result in a net safety benefit, and to establish the impact of using such equipment on emergency evacuation rates have been recently completed. In addition, research and development by the CAA to produce an equipment qualification standard for PPBE has also been completed.

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(1) Ontario Research Foundation, Airline Passenger Protective Breathing Equipment Study, Transportation Development Centre, Montreal, August 1986, 122 PP., TP7391E.

A total of 20 accidents were reviewed by the FAA (Document # DOT/FAA/CT88/03) in the net safety benefit study. The results of the study concluded that 80 lives out of 1,020 would have been saved due to PPBE, assuming there was no delay in evacuation due to donning. Donning delays would further reduce this figure which in itself is very sensititive to assumptions made in the analysis.

Arguments both for and against the portable passenger smoke protection equipment have been voiced over the past 20 years, and in that time no clear case has emerged which would justify mandatory carriage on transport aircraft. Therefore, the major thrust in improved fire safety and survival has been directed at the fire hardening of aircraft materials, with a view not only to reducing the risk of a fire but to delaying its development. Such delays in fire development would not only extend the survival time but, by reducing the contribution of the furnishing material to the total fire load, may also reduce the release of noxious and toxic fumes. Another factor that caused primary effort in this direction resulted from the fact that fire hardening was not perceived to have any possible adverse effects upon safety, whereas simple smoke hoods had been found to have potentially fatal consequences if used incorrectly(2).

Aircraft fires involving risk to life can be classified as either post-crash or in-flight fires. Post-crash fires generally develop as a result of ignition of jet fuel released from storage tanks damaged by the crash. They are characterized by high radiant heat loads, some damage to the fuselage and relatively short periods of time to the flash-over condition. Flash-over involves the rapid growth of the fire from an area in the immediate vicinity of the fuel fire to the remaining cabin interior. Therefore, it is not considered realistic to provide survival equipment beyond the flash-over point. The following section will, therefore, discuss the survival equipment which will provide protection of respiration, vision and maintenance of occupants in a conscious and mobile state until evacuation has been successfully completed(3).

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(2) Civil Aviation Authority, Discussion Paper - Passenger Smoke Hoods, Paper No. S 836 Issue 1, 18 July 1986.

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(3) Ontario Reseach Foundation, Airline Passenger Protective Breathing Equipment Study, Transportation Development Centre, Montreal, August 1986, 122 PP. TP7391E.

2. APPLICABLE BACKGROUND DATA AND LIMITATIONS

The purpose of this section is to describe the results of the equipment manufacturer survey. Based on the survey, equipment types and development status is reviewed, sizes and weights of PPBE units are estimated, and the PPBE systems considered for this study are discussed.

2.1 Evolution of Equipment Manufacturers/Types

The development of PPBE's can be traced as far back as 1965, when a research unit fabricated the first two prototypes of an FAA passenger smoke hood. Development was continued by the Sheldahl company, utilizing two basic types, a rebreathing unit, and one with ventilation provided by disposable compressed gas cylinders. Various metal coatings were also tested to minimize heat transmission.

Following a revision to the FAR's in 1967 dealing with crashworthiness, an industry committee under the auspices of the Aerospace Industries Association (AIA) in the United States evaluated eight different types of PPBE. All were considered to be unsatisfactory due to two major problems, namely: lack of adequate sealing against smoke and fumes; and lack of adequate visibility.

Use of these devices in low illumination actually slowed evacuations. A controlled FAA test on a Boeing 720 in 1968 concluded that "... the use of smoke hoods ... causes a small increase in the overall time required for naive passengers to evacuate"(1).

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(1) Federal Aviation Administration, Summary Report of the History and Events Pertinent to the Civil Aeromedical Institute's Evaluation of Providing Smoke/Fume Protective Breathing Equipment for Airline Passenger Use, Oklahoma City, OK, June 1987, DOT/FAA/AM-87/5.

Despite these problems, the FAA issued a Notice of Proposed Rule Making (NPRM) in 1969 requiring smoke hoods for all operations conducted under FAR 121 and FAR 125. After a sequence of hearings, the NPRM was withdrawn in 1970, with potential evacuation delays cited as the major reason.

Interest lagged once again until 1980, when PPBE research was again suggested as part of a more general effort to combat the results of inflight fires. New tests in 1981 suggested that the most promising device was "a passenger oxygen mask modified to incorporate a controlled use rebreather resevoir in addition to, but separate from the oxygen reservoir."(1)

Following the Air Canada DC-9 accident in 1983, research was initiated by the Administrator of CATA as part of an overall programme to upgrade fire safety. This has resulted in the commissioning of both the Ontario Research Foundation study as well as the present PPBE study.

2.2 Equipment Manufacturer Survey

Twenty equipment manufacturers were identified and contacted in an attempt to establish a current data base of real data for PPBE. The equipment manufacturers, including two major European air carriers, are listed in Table 2.1. The survey commenced in early December 1987, and was concluded by mid March 1988.

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(1) Federal Aviation Administration, Summary Report of the History and Events Pertinent to the Civil Aeromedical Institute's Evaluation of Providing Smoke/Fume Protective Breathing Equipment for Airline Passenger Use, Oklahoma City, OK, June 1987, DOT/FAA/AM-87/5.

TABLE 2.1 - MANUFACTURERS SURVEYED

WALTER KIDDE CO. LTD. Belvue Road, Northolt, Middlesex, UB5 5QW, England

SABRE SAFETY LTD. 225 Ash Road, Aldershot, Hants, GU12 4DE, England

SAFELAB SYSTEMS LTD. Bush House, 72 Prince Street, Bristol BS1 4HU, England

NORMALIER-GARRET LTD. HQ Div. P.O. Box 2, Yeovil, Somerset, BA20 2YD, England

RECAL SAFETY LTD. Beresford Ave., Wembley, Middlesex HAO 1QJ, England

MSA (BRITAIN) LTD. East Shawhead, Coatbridge, ML5 4TD, Scotland

CHARCOAL CLOTH LTD. 21 Haviland Road, Ferndown Industrial Estate, Wimbourne, Dorset BH 21 7RZ, England

LIFE SUPPORT ENGINEERING LTD. Robell Way, Storrinton, Sussex, RH 20 3SDN, England

L'AIR LIQUIDE - DTA P.O. Box 15, 38360 Sassenage, France

E.I. DUPONT DE NEMOURS & COMPANY (INC.) Finishes and Fabricated Products Division. Wilmington, Deleware 19898

J.S. STEWERT 74 The Common Parbold, Winigan WN8 7EA, Land, England

EMERGENCY RESPIRATORY OXYGEN SYSTEMS, BP 10 78371 Plaisir Cedex, France

DME CORPORATION 111 S.W. 33rd. St., Ft. Lauderdale, FL, U.S.A. 33315

SCOTT AVIATION 225 Erie St., Lancaster, New York, U.S.A. 14086

DRAGERWERK AKTIENGESELLSCHAFT Moislinger Allee 53/55 P.O. Box 13 39 D-2400 Lubeck

CYPERTRONICS LTD. P.O. Box Twyford, Berkshire, RG 10 9L R, England

PURITAN-BENNET AERO SYS. CO. 10800 Pflumm Road, Lenexa, Kansas, U.S.A. 66215-2198

BOIENG COMMERCIAL AIRPLANE COMPANY P.O. Box 3707, Seattle, Washington, U.S.A. 98124-2207

KLM ROYAL DUTCH AIRLINES P.O. Box 7700-1117 ZL Schiphol Airport the Netherlands

LUFTHANSA GERMAN AIRLINES - Ham If 1 - Weg Beim Jager 193 D-2000 Hamburg 63, Germany

The survey was intended to aid in the compilation of the type of information summarized in Table 2.2.

2.3 Results of Equipment Manufacturer Survey

Of the twenty companies surveyed: Ten were non-responsive; three were no longer pursuing PPBE as of March 1988; four equipment manufacturers were actively pursuing PPBE development; three manufacturers disclosed prototype designs but were still involved in the development phase. Details of the survey are discussed in subsequent sections.

2.4 Equipment Types and Development Status

The primary design goal faced by the equipment manufacturers is to design a compact, lightweight unit which complies with the governing PPBE specifications. Since PPBE specifications for transport category aircraft were at draft status as of March 1988, several equipment manufacturers were uncommitted to final or prototype design pending formal adoption of an equipment standard. Several functional characteristics, namely: the required protection time that must be provided by PPBE and the consideration of hypoxia protection which could also be afforded by PPBE are critical considerations to prototype design. These were not firmly established as of March 1988.

Some manufacturers, principally those involved with the design of filtration based PPBE, have encountered a significant problem in meeting the PPBE draft specification requirements which require less then 5 percent of the challenge atmosphere leaking into the inspired volumes throughout the test profile (ref. AS8048 Draft Specification Appendix 'A'). Carbon monoxide is the primary problem contaminant. This consideration alone is presenting a significant impasse for

TABLE 2.2 SURVEY PARAMETERS

- Data base of PPBE which satisfy current draft PPBE specifications and would be likely and available candidates for implementation into transport category aircraft.
- Data base of PPBE currently under development which are likely to satisfy PPBE draft specifications for transport category aircraft.
- Weight of candidate PPBE currently under development.
- Dimensional data of candidate PPBE currently under development.
- Functional characteristics of candidate PPBE currently under development.
- System characteristics of candidate PPBE currently under development.

PPBE filtration based systems at present. At the time of the survey, no viable filtration based PPBE were identified. It is worthy of note that a considerable effort is being expended by industry in filtration technology, however at the time of this survey, neither weight or geometry characteristics of possible future viable filtration PPBE could be firmly established.

One manufacturer indicated that they were pursuing a PPBE unit as well as a combined smoke/hypoxia protection unit. The latter would be a candidate replacement scheme for existing oxygen masks; oxygen would be supplied to the unit from the aircraft oxygen system until such time that passenger mobility was required. An integral oxygen supply would then be activated upon detachment from the parent oxygen system for a short time period. Whether a filtration system could provide the short term protection is not known at present. The size of the PPBE unit is targeted at allowing for replacement of existing oxygen masks. Another manufacturer indicated that they were pursuing a patent for their PPBE unit design. The only data offered was the size of the unit at about 8.9 cm x 8.9 cm x 11.4 cm (3.5 in. x 3.5 in. x 4.5 in.).

It is noteworthy that there exists a markedly competitive condition in the industry. Therefore, some manufacturers are not disclosing design concepts or prototype details while patents are sought.

In conclusion, the results of the survey are considered quite limited. Due to physical size, the ability to meet challenge atmosphere requirements, and development status, only two gaseous based oxygen PPBE units were identified as likely candidates, both are still in the prototype development phase, and both are somewhat bulky and heavy. Whether these units will in fact satisfy forthcoming PPBE specifications affecting their use in transport category aircraft is presently unknown.

2.5 Range of PPBE Unit Sizes

Self-contained, non-filtration based PPBE's examined were bulkier and heavier than the prototype filtration based PPBE designs examined. A self-contained source of oxygen (gaseous or chemical) is required for non-filtration based systems, these tend to be bulkier and heavier than the speciality treated hybrid cloths used in some filtration PPBE systems. It is noteworthy to highlight that this may not be true for future filtration PPBE developments which do meet adopted standards, or, the units designed for crew usage. It is believed that some non-filtration based PPBE designs are likely to be successful in complying with future PPBE specification. Several manufacturers feel that these units will be significantly reduced in size as development matures. It is therefore conservative to establish an upper bound to the 'PPBE unit size envelope' based on available prototypes. The lower limit on the 'PPBE unit size envelope' is not as discernible. One manufacturer's design goal is to downsize the unit to an existent hypoxia oxygen system enclosure. Assuming this design goal is realized, an additional 20% volume is added for conservatism. The resulting volume will be considered as the lower bound of the 'PPBE size envelope'. As previously noted, existing filtration based systems identified in this survey are not compliant with the PPBE draft specifications (See Section 3.6). It would therefore not be appropriate to establish a conservative lower bound on the 'PPBE unit size envelope' based on the filtration PPBE types available.

Adding a nominal 5% allowance to the upper and lower PPBE size envelopes for the stowage enclosure results in the volumes depicted in Table 2.3.

For the purpose of this study, a 'mean PPBE size envelope' is established and is defined as:

$\frac{1}{2}$ x ('Upper PPBE size' + 'Lower PPBE size')

Utilizing the 'mean PPBE size envelope' for subsequent analysis is intuitively appealing, and, justified as follows:

- Using a size 'range' would lead to a difficult and ambiguous cost analysis.

- Using a smaller size envelope may lead to a non-conservative cost analysis.

- Using a larger envelope would imply disregarding manufacturer claims that size reduction is inevitable, and thereby restricting the scope of the study implications to the immediate present.

The 'mean PPBE size' envelope will be used for analysis purposes henceforth in this study.

2.6 Weight of PPBE units

The weight of most PPBE units may be split into four distinct components. The fourth weight component may or may not be applicable and is dependent on the stowage and presentation system scheme.

1) The polymer layers which form the PPBE unit shell and carbon dioxide scrubber.

TABLE 2.3 - PPBE SIZE ENVELOPES[1]

	Upper limit		Lower limit		Mean	
	in.	cm.	in.	cm.	in.	cm.
Dimension 1	9.0	22.9	4.7	11.9	6.8	17.3
Dimension 2	2.2	5.6	2.0	5.1	2.1	5.3
Dimension 3	5.9	15.0	5.4	13.8	5.7	14.5
Volume	117	1917	51	836	84	1376

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(1) The dimensions include an allowance for the stowage enclosure.

2) The packaging.

3) The oxygen supply system or filter system.

4) Stowage/presentation enclosure.

Items 1 and 2 will vary only marginally from one type of PPBE unit to another. From data obtained by weighing a sample PPBE unit, the following results are obtained:

Weight of item 1 is about 0.045 kg (0.1 lb.).
Weight of item 2 is about 0.091 kg (0.2 lb.).

Item 3 is dependent on the nature of the self-contained system, or whether the system is dependent on aircraft oxygen supply. It is possible that future filtration based systems be potentially lighter than systems which are dependent on aircraft oxygen supply, or those which have an integral gaseous or chemical oxygen supply. However, as noted previously, it would be unjustified to quantitatively consider filtration based systems at this time. A system which is partially dependent on aircraft oxygen supply would still require a small self-contained oxygen source to satisfy the five minute mobility requirement addressed in the PPBE specifications. Therefore, the system weight would most likely approach that of a completely self-contained system. Assuming that a completely self-contained system with an integral gaseous oxygen cylinder is utilized, a conservative upper weight limit for item 3 is about 0.36 kg (0.8 lb).

Item 4, the weight of the stowage/presentation enclosure and hardware, will be dependent on the stowage/presentation scheme considered. Item 4 will therefore be considered as a dependent variable, and quantified as each stowage and presentation scheme is examined.

The total weight which will be associated with individual PPBE units for analysis purposes in this study will therefore be 0.50 kg (1.1 lb) plus the weight of the stowage/ presentation system, if required.

Considering PPBE unit weights to a maximum of 1 kg (2.2 lb), the weight increase penalties manifest themselves principally as increased aircraft operating costs. Perhaps less pronounced, but worthy of note, are the added engineering costs required to design the PPBE installation/restraint, damper overhead presentation PPBE to avoid possible passenger injury, and review the effect of added mass on the structural integrity of the systems onto which the PPBE locate.

2.7 PPBE Systems Selected

Three types of PPBE systems are identified, two of which will be used for further analysis in this report.

1) Filter type - self-contained.

   Although future research and development of filtration based systems may lead to a viable PPBE, current prototype systems may not be quantitatively considered for PPBE implementation. As previously noted, the filtration based PPBE designs examined did not meet specification requirements with respect to isolating the challenge atmosphere.

   Since no viable design was available at the time of this study; sizing, functional considerations, costing and stowage requirements are unavailable. For these reasons alone, further treatise of filtration based PPBE is limited to discussion. Much of the presentation and stowage criteria for self-contained breathable gas PPBE is nevertheless applicable to filtration based PPBE.

2) Breathable gas supply - self-contained.

This self-contained PPBE, with integral breathable gas supply, is viable as evidenced by prototypes, and will be considered in this study.

3) Breathable gas supply - partially dependent.

A 'breathable gas supply - partially dependent' scheme is defined as one that has the following characteristics:

- The unit is initially connected to a remote breathable gas supply from which the long term non-mobile protection is afforded.
- The unit is partially self-contained in that it affords the user the required mobile protection for evacuation once disconnected from the remote breathable gas supply.

The above schemes are considered in this study. However, a PPBE unit which requires the passenger to 'connect' his/her unit to a supply outlet is not considered since it would violate applicable PPBE specifications in Section 3.

3. AIRWORTHINESS REQUIREMENTS

This section addresses the relevant regulations pertaining to PPBE. More specifically, Federal Aviation Regulation (FAR) 25, FAR 91, FAR 121, Joint Airworthiness Requirements (JAR) 25 and the Canadian Air Navigation Orders (ANO) are addressed. Furthermore, three PPBE specifications are considered in this section.

3.1 General

Notwithstanding a desirable need or the requirement to install a PPBE system in an aircraft, requirements that finally govern a specific installation in a particular type or model of aircraft are the airworthiness regulations. These regulations can be a result of the design standards that govern the particular type of aircraft, or can be the operational requirements that demand additional airworthiness standards for a particular type of operation such as a commercial fare-paying passenger operation.

The requirements that follow have been extracted from various design and operational requirements primarily common to North America but also recognized throughout the world. These deal exclusively with the installation of the equipment as opposed to the equipment itself. They govern the location, the availability and the recognition by the passenger and crew as to what to do with the PPBE equipment should such equipment be required. The physical shape and size may in fact have an influence on the final location, but the requirements are fundamentally the same:

- The PPBE must be stowed safely, from a passenger's protection point-of-view.

- It must be readily accessible by the passenger, it must be readily inspectable from an operator's point-of-view, whether by flight crew or ground maintenance personnel.
- The environment in which it is contained must assure serviceability.
- The device must be accessible by the passenger under all emergency conditions, including the potential failure of automatic deployment systems.

In addition to the above, if a PPBE is installed in an aircraft, the installation must be compatible with, and not override other mandatory equipment requirements such as life-vests, inter-crew communication systems, megaphone use by crew, underseat usage by passengers to stow luggage, the primary oxygen systems if combined and evacuation requirements. The PPBE must be available to all occupants should the need arise, including the infants who are on the lap of an adult arbitrarily located somewhere within the cabin.

FAR 91.193, FAR 121.303, FAR 121.309, FAR 121.318 and FAR 121.319 either directly or indirectly impose the need for all emergency type of equipment to be readily available to crew and passengers. As in the case of the public address system and crewmember interphone system, PPBE must be capable of being accessed and donned within 10 seconds.

A fire at altitude, requiring crew intercommunication, public address system and PPBE's, would almost rule out the possibility of using any system other than one that can provide all services at the same time for a substantial period of time, along with oxygen and PPBE mobile devices for a finite period of time.

The titles of the relevant airworthiness regulations which affect the installation of PPBE are listed in Sections 3.2 through 3.5. A brief discussion, where necessary, may be found in Appendix A. These requirements are those which will primarily govern the cost in time and money for the installation of a PPBE system on any large commercial aeroplane in the Western world.

3.2 FAR 25 Airworthiness Standards: Transport Category Airplanes (Amendments 1- 61 Jan. 1987)

FAR 25 addresses the following conditions: (More details regarding the relevant FAR 25 paragraphs are included as Appendix A).

a) Emergency Landing Conditions (FAR 25.561 (c))

b) Materials (FAR 25.603)

c) Fabrication Methods (FAR 25.605)

d) Accessibility Provisions (FAR 25.611)

e) Material Strength Properties and Design Values (FAR 25.613)

f) Seats, Berths, Safety Belts and Harnesses (FAR 25.785)

g) Stowage Compartments (FAR 25.787)

h) Retention of Items of Mass in Passenger and Crew Compartments and Galleys (FAR 25.789)

i) Emergency Evacuation (FAR 25.803 (c))

j) Compartment Interiors (FAR 25.853)

k) Function and Installation (FAR 25.1301)

l) Equipment, Systems and Installations (FAR 25.1309)

m) Circuit Protective Devices (FAR 25.1357/1359)

n) Safety Equipment - General (FAR 25.1411(a),(b))

o) Chemical Oxygen Generators (FAR 25.1450)

p) Protection of Oxygen Equipment from Rupture (FAR 25.1453)

q) Equipment Standards for the Oxygen Distribution System (FAR 25.1445)

r) Equipment Standards for Oxygen Dispensing Units (FAR 25.1447)

s) Maintenance Manual (FAR 25.1529)

t) Safety Equipment (FAR 25.1561)

3.3 United States Government Operational Design Standards

This section describes the relevant U.S. Airworthiness requirements relating to: FAR 91 (General operating and flight rules) and FAR 121 (Certification and operations: domestic, flag, and supplemental air carriers and commercial operators of large aircraft).

Canada is in the process of adopting those additional airworthiness requirements that are contained within the FAA operational requirements. Therefore, the following FAA requirements are considered to fall within the Canadian Government's intent and should be considered as applicable to Canadian aircraft should PPBE units become mandatory. Details of those regulations, whose headings are summarized below, are included in Appendix A.

a) Emergency Equipment (FAR 91.193)

b) Demonstration of Emergency Evacuation (FAR 121.291)

c) Airplane Instruments and Equipment (FAR 121.303)

d) Emergency Equipment (FAR 121.309)

e) Material for Compartment Interiors (FAR 121.312)

f) Public Address System (FAR 121.318)

g) Crewmember Interphone System (FAR 121.319)

h) Supplemental Oxygen for Emergency Descent and for First Aid; Turbine Engine Powered Airplanes with Pressurization (FAR 121.333)

i) Emergency and Emergency Evacuation Duties (FAR 121.397)

3.4 European Design Standards JAR 25 (Mar 86)

JAR 25.561 through 25.1301 and 25.1411 through 25.1561 are the same as those of FAR 25 in a previous section. However, the JAR 25.1309 interpretation, as shown in the AMA/ACJ (Acceptable Means of Compliance and Interpretation/Advisory

Circular-Joint), is somewhat different to that of FAR 25.1309 in that it is more specific with respect to the relationship between probability and severity of effects on the occupants of the aircraft. For the purposes of this study, it is believed that the discussion on FAR 25.1309 (see Appendix A) is adequate.

It is to be noted that JAR's which have an "X" embedded in their number, such as 25X1306, imply that this is a standard that is not included in the FAR 25. Details of these specific JAR 25 paragraphs are included is Appendix A.

a) Precaution Against Injury (JAR 25X.1360)

b) Electrical Systems (JAR 25X.1362)

3.5 Canadian Government Aircraft Operational Requirements (Air Navigation Orders)

Details of the relevant ANO's whose headings are listed below are reproduced in Appendix A.

a) Aircraft Seats, Safety Belts and Safety Harness (ANO II #2)

b) Life Saving Equipment (ANO II #8)

c) Oxygen Equipment (ANO II #9)

d) Restraint of Carry-on Baggage (ANO VII #4)

3.6 PPBE Specification Review

Three PPBE specifications are considered in this study, namely:

- CAA Specification No. 20 Issue 1 - Feb. 26, 1988.
- STPAe-CIN DTA/SG 64/RZ/MB/MF - 64.306 - Mar. 26, 1986.
- S.A.E. A-10 PPBE draft specification - Dec. 2, 1987.

Tables 3.1, 3.2 and 3.3 include excerpt paragraphs from the three specifications, respectively, which specifically relate to PPBE stowage/presentation considerations. The reader is referred, however, to the original document if more detailed information is required.

The paragraphs reprinted are considered to specifically relate to PPBE stowage/presentation parameters. Most of these considerations are addressed throughout this report. Other paragraphs are noted, but considered to be primarily PPBE unit design requirements.

3.6.1 CAA Specification (See Table 3.1)

The CAA specification, by the British Government, was updated and reissued on February 26, 1988. Table 3.1 has been compiled and reflects those paragraphs which specifically relate to PPBE stowage and presentation considerations. The following is a brief review of the contents within Table 3.1.

a) Paragraph 3.15.2 requires that the equipment shall have a means of determining the serviceability in the stowed position, except that such a requirement does not pertain to chemically generated oxygen units. Assuming that this requirement is referring to the basic design standard contained in JAR 25.1441, other than JAR 25.1441(c), it requires that the crew be able to readily determine, during flight, the amount of gas available, regardless of the system used other than those using chemically generated gas units. Therefore it places the responsibility on the installer to make such provisions

TABLE 3.1 EXCERPTS FROM C.A.A. SPECIFICATION PAPER NO. 20 ISSUE 1, DATED FEBRUARY 26, 1988. APPLICABLE TO STOWAGE AND PRESENTATION CONSIDERATIONS

Paragraph #	Description
3.2	- The equipment, as installed, shall be capable of being put into effective use by the wearer within 10 seconds of its need being recognized. This time shall include the time taken to remove the equipment from its stowage.
3.6	- The equipment performance shall not be critically dependent upon the facial size or shape of the wearer and shall be capable of effective use by male and female adults within the 2nd to 98th percentile critical head/body dimensions.
3.15.1	- The equipment shall have a reliability acceptable to the C.A.A.
3.15.2	- The equipment shall have a means to determine serviceability in its stowed position except for those that use chemically generated oxygen units.
3.16.1	- In addition to the requirements of JAR 25.1411 (b) the equipment stowage shall be readily accessible to the passenger when seated, when standing adjacent to their seats, and when standing in the aisle.
3.16.2	- Where the effective life of the equipment is dependent upon storage in an hermetically sealed valise, or equivalent, release from such a valise shall be concurrent with the removal of the equipment from its stowage and shall not require any separate secondary action. This requirement shall apply even where the equipment is automatically presented to the passenger.
3.16.1	- The equipment shall be free of any features which might snag or otherwise become entangled with any part of the passenger cabin interior or escape route, resulting in either equipment damage or delay in evacuation.
3.17.2	- The equipment shall be lightweight and as compact as possible so as not to interfere significantly with passenger mobility during and emergency evacuation.

TABLE 3.1 Continued

3.17.3	- Consistent with the requirements of para 3.17.2, the equipment shall be sufficiently robust to withstand adverse treatment likely to be experienced in an emergency.
3.19.1	- All materials used in the construction of equipment shall be flame resistant to the requirements of JAR 25.853, C.A.A. specification no. 8 or an equivalent specification.
3.19.2	- All exposed surfaces of the PPBE must withstand the effects of: a) Radiant heat at 1.7 watts/cm2 for a period of not less than 90 seconds. b) In addition to the requirements of para 7 (Transient temperatures of 100 degrees C for not less than 5 minutes) transient ambient air temperatures of up to 200 degrees C for not less than 30 seconds.
4.2	- The equipment, whether automatically presented or requiring removal from its stowage by the intended wearer, shall be so designed that the supply of breathable gas is automatically initiated and requires no specific action by the wearer.
4.3	- Where the breathable gas is provided by a chemical generator, the generator shall comply with the requirement of JAR 25.1450.
4.3.2	- All storage cylinders and components under pressure either when stowed or in use shall comply with the requirements of JAR 25.1438 and 25.1453, as appropriate. In particular, storage cylinders shall be provided with means to prevent rupture when exposed to high temperatures. Such devices must not however cause the loss of supply to the wearer when the equipment is exposed to the conditions of para 3.19.

TABLE 3.1 Continued

4.3.3	- Where the gaseous supply is remote from the equipment, eg. a chemical oxygen generator located overhead in the passenger service unit, means shall be provided to detach, without leakage, the supply source from the protective breathing equipment when the equipment is required for use whilst evacuating the aircraft. The release means shall be simple and obvious but shall be adequately protected from inadvertent operation.
6.1	- The equipment, as installed within the aircraft, shall adequately resist the effects of vibration when tested in accordance with RTCA DO-160B, Table 8-1, category a or its equivalent.
6.2	- The equipment, as installed within the aircraft, shall adequately resist the inertia forces specified in JAR 25.561 and after exposure to such forces shall operate normally.
6.3	- The equipment shall be adequately protected from adverse effects of ozone and ultra violet light and humidity.
6.4	- In addition to the required operational altitude range for the equipment required by para 3.9, all equipment, when stowed, shall not adversely be affected by decompression at 30,000 ft at a maximum of pressure change equivalent to 1000 mb/min.
6.5	- The equipment shall provide the level of protection called for in para 3.11 at an ambient temperature of +20 degrees C having been subjected to stowage temperatures of -10 degrees C to +50 degrees C and shall continue to provide this level of protection when exposed to the transient temperatures specified in para 3.19.2 (b).
6.6	- The equipment shall survive without adverse effect, extreme stowage temperatures of -45 degrees C to +70 degrees C.

available to the crew. In the case of an aircraft system the problem is similar to the oxygen supply question, but for systems using other than the chemically generated units, there must be a means provided so that the crew can determine the extent of supply available at each supply source.

b) Environmental Requirements (Paragraphs 6.1 to 6.6)

Although these requirements are directed at the equipment itself, the installation will have to be designed and/or located to assist the equipment in meeting these requirements; at least the installation must be such as to allow for these environmental factors to not be exceeded.

3.6.2 STPAe - Specification (Table 3.2)

The STPAe - CIN, the French Government Draft Specification, was issued on March 26, 1986. Table 3.2 summarizes the relevant PPBE stowage and presentation considerations.

3.6.3 SAE - Specification (Table 3.3)

The 'Engineering Society for Advancing Mobility Land Sea Air and Space' (SAE) draft specification was reviewed and dated December 2, 1987. Table 3.3 summarizes the paragraphs of the specification which specifically relate to PPBE stowage and presentation considerations.

3.6.4 General Conclusions to the Specifications

As highlighted in this section, current draft PPBE specifications require that the equipment, as installed, shall be capable of being placed into effective use by the wearer

TABLE 3.2 - EXCERPTS FROM STPAe - CIN DRAFT SPECIFICATION DATED MARCH 26, 1986. APPLICABLE TO STOWAGE AND PRESENTATION CONSIDERATIONS

Paragragh #	Description
Introduction	- This draft standard defines the minimum specifications for a breathing device to protect passengers from smoke and hypoxia at all altitudes.
Performance	- The donning of the device in an emergency situation shall be simple and fast. The protective device must not hinder the user in any way during evacuation and must be compatible with evacuation measures.
5.3	- When the device can be disconnected from the oxygen source, evacuation should be possible 30 seconds after donning of the device.
6.5	- The time required to don the device and for it to start operating must not exceed 15 seconds.

TABLE 3.3 EXCERPTS FROM SAE A-10 AS-8048 DRAFT SPECIFICATION DATED DECEMBER 2, 1987. APPLICABLE TO STOWAGE AND PRESENTATION CONSIDERATIONS

Paragraph #	Description
3.1.1	- The equipment shall not cause an unacceptable hazard to the user or the aircraft during stowage or use, and shall satisfy the applicable sections of the reference documents.
3.1.3	- The equipment shall be supplied with a means to determine serviceability while in its stowed condition.
3.1.5	- The stowed/stored unit shall not be adversely affected by environmental extremes.
3.1.6	- The equipment shall have a 98% minimum reliability factor at 90% confidence level during its design service life.
3.1.8	- Donning and doffing shall be easily accomplished without undue reliance upon pre-flight briefing and instruction.
3.1.9	- Failure modes effects analysis of the equipment shall be provided.
3.2.8	- The equipment shall be capable of being donned and operational within 10 seconds by users.
4.1	- The unit and its case shall be constructed of materials that are flame retardant and satisfy the requirements of FAR 25.853 (b) or ATS 1000.
4.10	- The equipment shall be free of any features which could become entangled with aircraft interiors.

within ten seconds of its need being recognized. This time period includes the time required to remove the equipment from its stowed position. Additionally, the specification requires that the removal of the PPBE unit from its stowed position shall not require any separate secondary action. The following general and specific conclusions can be drawn from these draft requirements:

a) The unit must be accessed from the stowed or presented position in a minimum time period. The time period required to don any given PPBE unit is unknown at present, therefore, the time required to access and retrieve the unit must be minimized.

b) Separate secondary action is not allowable. This includes unfastening a seat harness to gain access to the unit.

c) Simultaneous coordinated action with both hands is undesirable. With a single hand, the user should be able to access and retrieve the unit. It is worthy of note that although this criteria is strictly interpretive, maximum reach coordinated hand action is dependent on individual dexterity. Also, simultaneous coordinated action with both hands would unquantifiably restrict the size of the reach envelopes. A discussion for physically disabled people, where two hands may be required is described in Section 5.3.

An emergency scenario requiring the immediate usage of a PPBE unit is subject to occurrence during the landing or take-off phase of a flight. The location of either an "automatic presentation" PPBE system or a "passenger self-help" system is thus constrained by the reach envelope of the subject passenger who is belted into his/her respective seat position. Should the PPBE unit be a stowed self-help type or presented automatically, the user should be able to gain immediate unobstructed palms reach access to the unit.

Section 4 will describe in more detail the generation of these reach envelopes.

4. CONCEPT DEFINITIONS AND LIMITATIONS

The objective of this section is to identify and define viable stowage/presentation schemes. Based on the passenger reach envelopes and the aircraft interior configuration review, a number of stowage/presentation schemes are identified and defined.

4.1 Generation of Reach Envelopes

So that acceptable stowage locations may be readily identified, "passenger reach envelopes" were generated. The mathematical qualification for the plots and the programming parameters are included in Appendix B. The methodology used to generate the envelopes is highlighted in Table 4.1, while Figure 4.1 depicts a three dimensional view of a typical envelope as well as the standard X-Y-Z aircraft coordinate system and datum point.

Figures 4.2 and 4.3 present plan views of the reach envelopes in the X-Y plane of a 5 percentile women. Each contour represents the maximum passenger reach at a specific waterline (elevation). Any envelope at a given waterline may be interpolated graphically. Figures 4.2 and 4.3 can be repeated for different seating arrangements and combined with different boundary conditions allowing one to derive the following useful information:

- Permissible "self-help" stowage locations with respect to any given seating arrangement or interior arrangement.

- Permissible "automatic presentation" stowage locations. One may "map" a chosen envelope onto a surface considered for stowage, ie. for an overhead presentation system. One air carrier may wish to present the PPBE

TABLE 4.1 - METHODOLOGY OF GENERATING PASSENGER REACH ENVELOPES

- Passengers are considered seated and restrained by a lap harness.
- Seated body dimensions were chosen from MIL-STD-1472.
- The five percentile women body dimensions were utilized as recommended in the SAE draft specification of Section 3.
- The two percentile women body dimensions as recommended in the CAA specificatin of Section 3 were not included.
- Mathematical equations consider the upper body to rotate a maximum of 75 degrees about the upper hip in the X-Z plane(1). Upper body rotation in the Y-Z plane is not allowed due to possible obstruction from seat arms and other passengers. Arm rotation is unconstrained.
- Maximum reach is defined by the maximum reach of the palm of any single hand.
- Contour plots were generated in the X-Y plane for increments along the Z axis.
- Contour plots were generated in the X-Z plane for increments along the Y axis.

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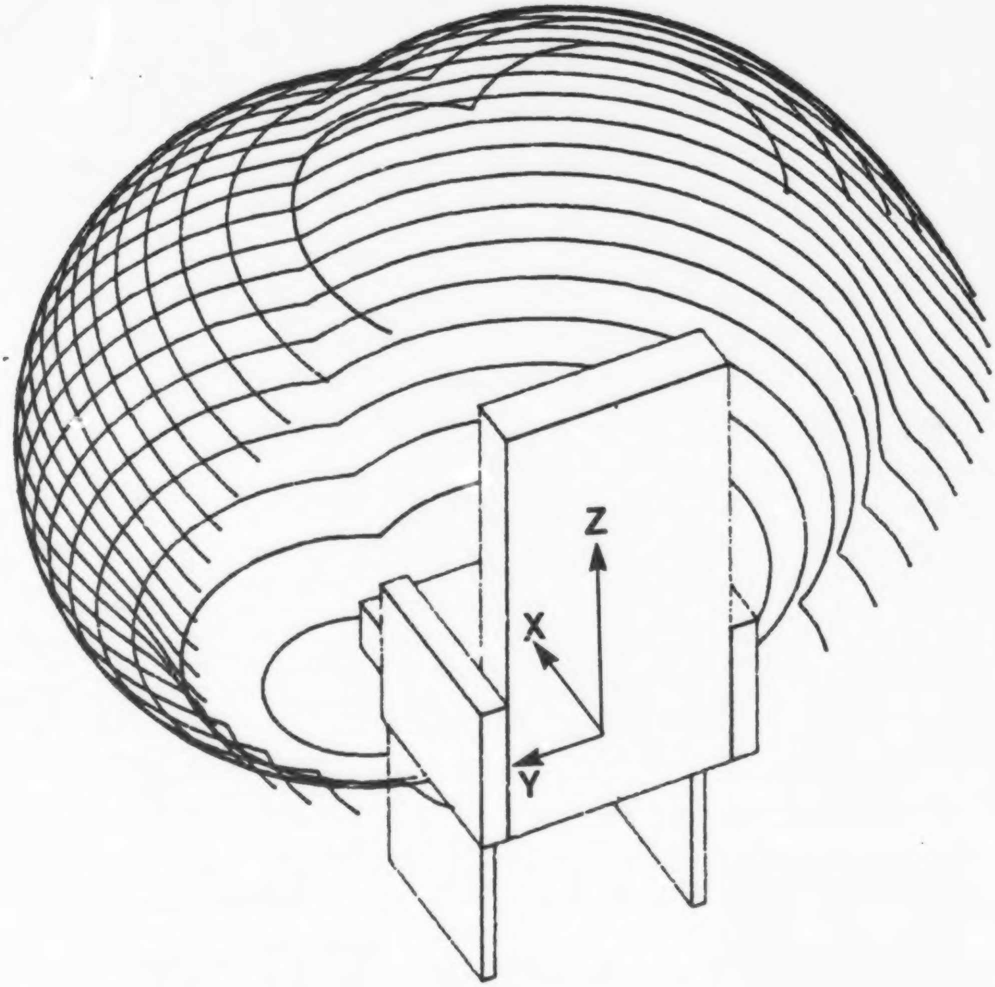
(1)Lower pivot points are not possible due to the seat harness restraint.

FIGURE 4.1

THREE DIMENSIONAL VIEW OF A PASSENGER REACH ENVELOPE

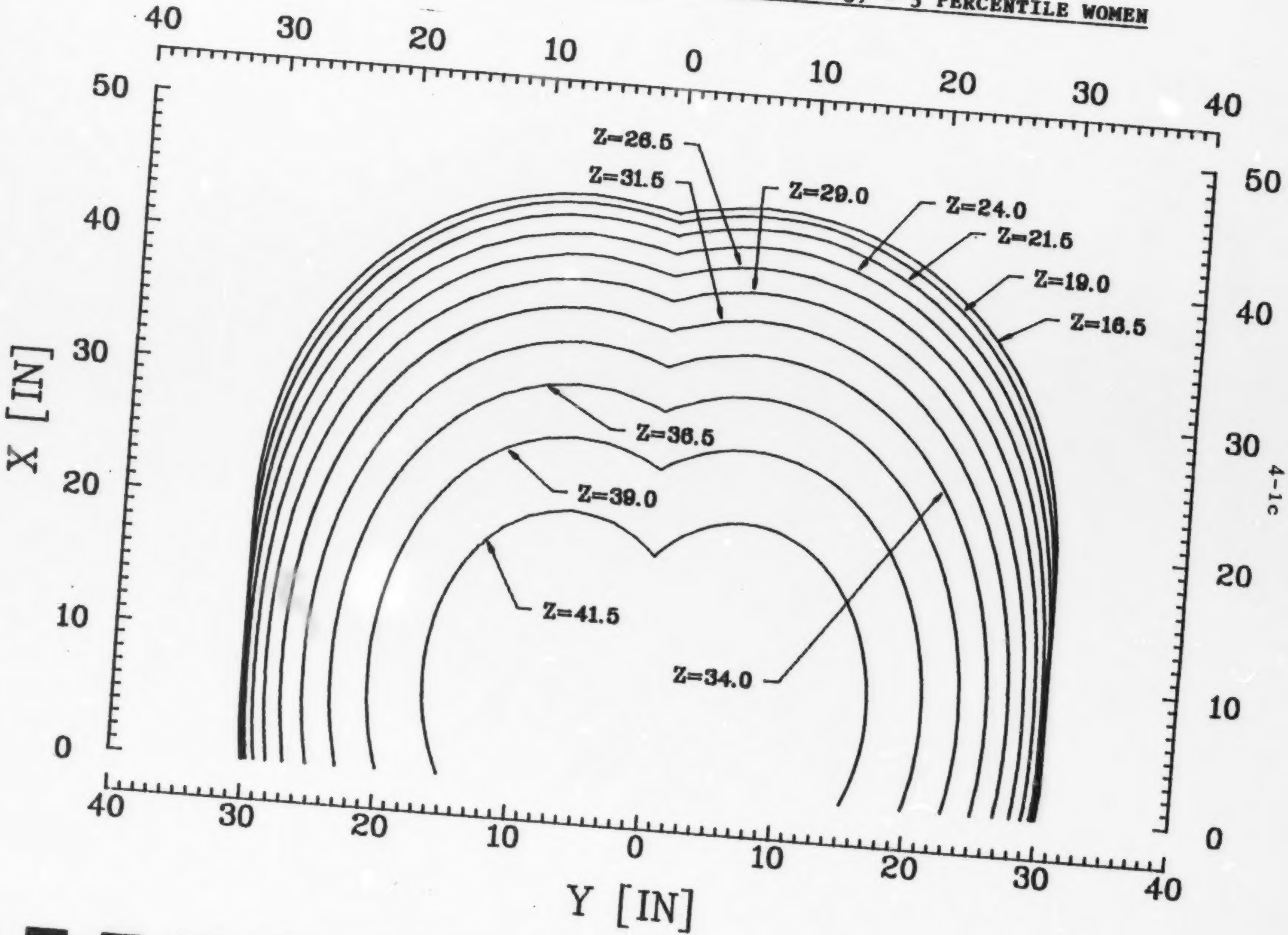


The reference X-Y-Z datum point is defined by the intersection of three planes as follows:

- Bottom seat cushion in the X-Y plane
- Back seat cushion plane in the Y-Z plane
- Center of seat in the X-Z plane

FIGURE 4.2

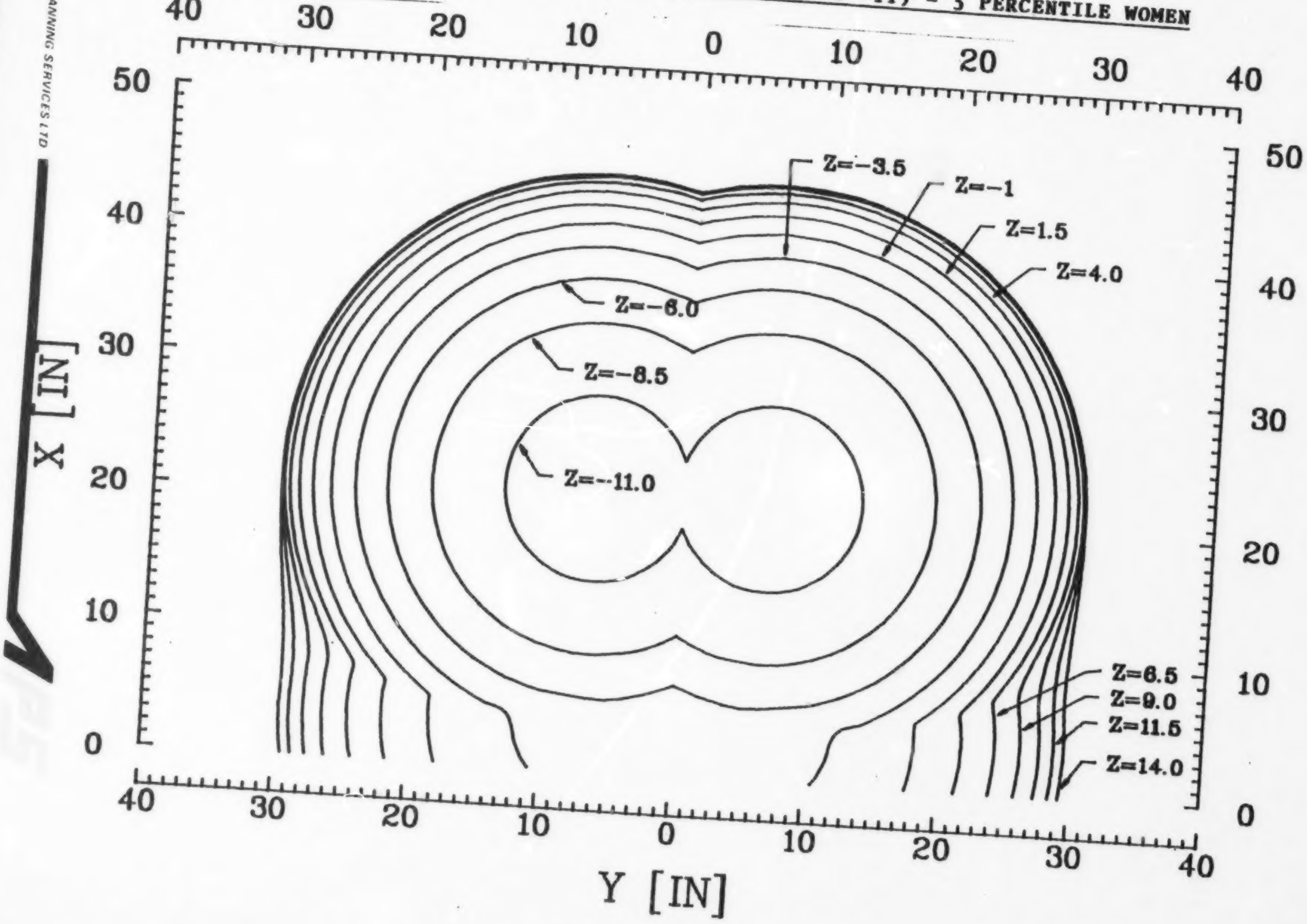
PASSENGER REACH ENVELOPE - X-Y VIEW (Z = 41.5 to 16.5) - 5 PERCENTILE WOMEN



SCALE 1:10

FIGURE 4.3

PASSENGER REACH ENVELOPE - X-Y VIEW (Z = 14 to -11) - 5 PERCENTILE WOMEN



SCALE 1:10

unit in the vicinity of waterline 31.5. One then translates the envelope corresponding to waterline 31.5. along the Z axis to the physical surface. Any part of the surface subsequently defined by the envelope is acceptable for a "drop down" presentation system, unless other physical constraints exist.

- Areas in which the envelopes overlap and are not adversely affected by constraints will describe areas where multiple PPBE units can be stowed for presentation. Combining the rationale of item (b), an optimized multiple stowage location can be obtained.

- Rapid identification of acceptable and unacceptable stowage/presentation locations;

Figure 4.4 is an X-Y example plot of a typical aircraft seating configuration for a 5 percentile woman.

Figure 4.5 is a plot viewed on the X-Z plane for a 5 percentile woman. The X-Z plot allows additional boundary conditions to be identified. This facilitates determination of such information as:

- Maximum allowable seat pitch for underseat and seat-back based self-help stowage schemes.

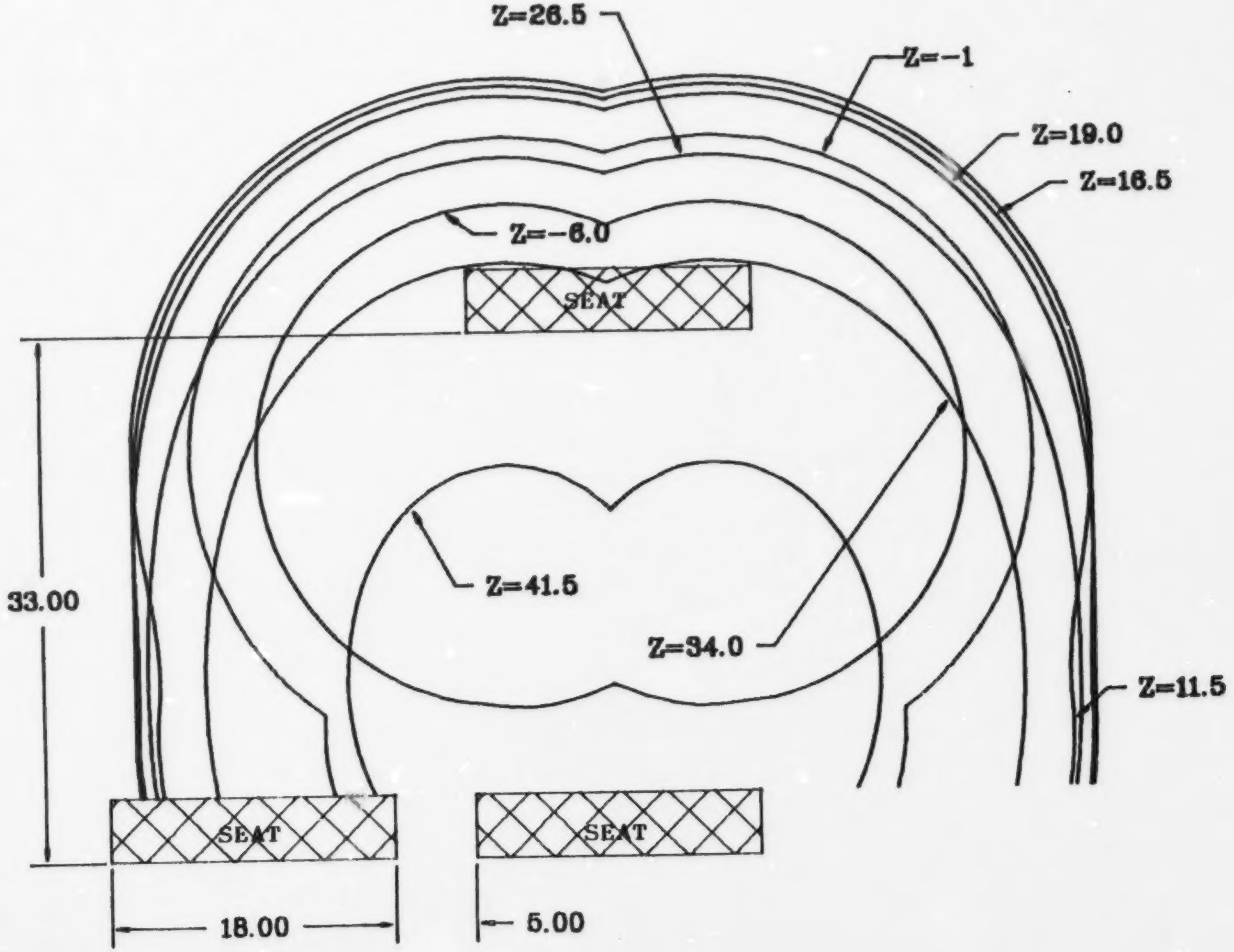
- Correlation of X-Z plane field of vision with presentation schemes.

- Adverse effects of seating discontinuities.

- Rapid identification of acceptable and unacceptable stowage/presentation locations.

FIGURE 4.4

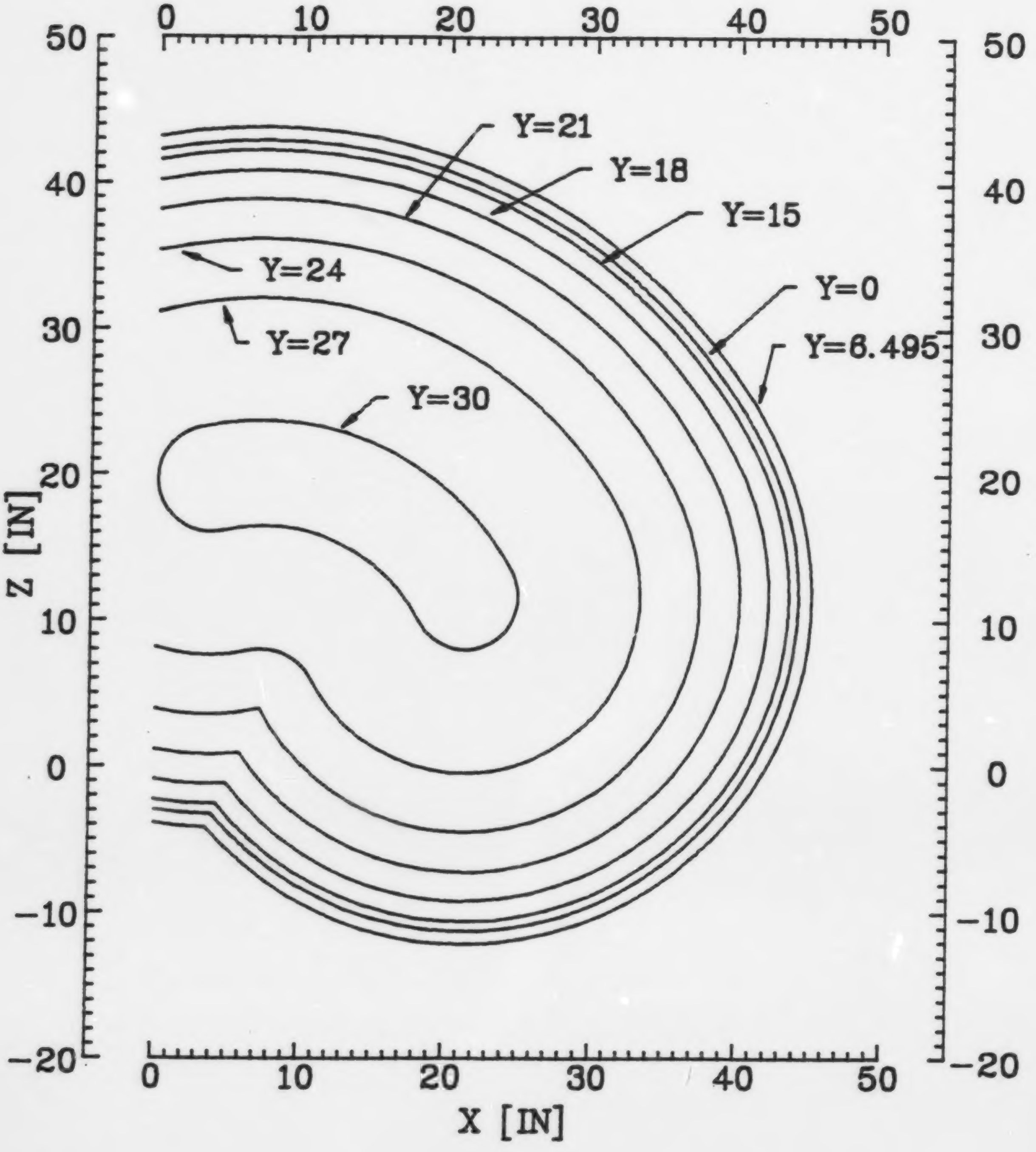
PASSENGER REACH ENVELOPE - TYPICAL AIRCRAFT SEATING - X-Y VIEW-5% WOMEN



SCALE 1:10

FIGURE 4.5

PASSENGER REACH ENVELOPE - X-Z VIEW - 5% WOMEN



SCALE 1:10

Translation mapping along the "Y" axis and interpolation between plot contours are analogous to the X-Y plane plots.

The upper limit of a passenger envelope (95 percentile or greater man) will assert a constraint on the allowable stowage and presentation location. For overhead presentation, systems, the possibility of the PPBE striking the passengers head and shoulders upon presentation is undesirable. The constraint can be quantified by superimposing a plan view of the subject passenger envelope onto Figures 4.2 and 4.3. This can be done in a future study prior to the actual PPBE installation/implementation.

4.2 Aircraft Interior Configuration Review

4.2.1 Introduction

The methodology of conducting the interior configuration review was as follows:

1) A preliminary interior configuration review:

   - To establish the extent of interior configuration diversity in the fleet of aircraft identified by the statement of work for this study, and subsequently to establish interrelationships between aircraft types in order to reduce the raw data requirements.

   - To aid in the identification of possible stowage and presentation schemes for the PPBE unit size and presentation envelope.

   - To aid in the identification of both physical and functional constraints or limitations.

2) A final interior configuration review:

- To obtain data which would allow for detailed geometry review.
- To obtain data which would allow for a cost analysis for the principle schemes considered as feasible.

4.2.2 Preliminary Aircraft Configuration Review

The aircraft surveyed during the preliminary configuration review include the B-747 and low ceiling L-1011. An ample representation of these and other aircraft types considered is shown in Table 4.2, while Figures 4.7 and 4.8 illustrate a number of cross-sections for turbo-jet and turbo-prop aircraft, respectively. The interior scheme for each aircraft type is likely to vary depending on the model series number, refurbishment status, or custom interior finishing requirement. The number of possible unique interior arrangements for these representative aircraft alone therefore becomes ponderous.

The establishment of general interrelationships between aircraft types is limited. A few general examples follow:

a) Most Lockheed L-1011 series 100 aircraft have no center overhead bins, while the L-1011 series 500 have center bin arrangements.

b) Overhead geometries in outbound aisle seats in multiple aisle aircraft are generally more similar to overhead geometries in single aisle aircraft than to the center seating section of a multiple aisle aircraft.

TABLE 4.2 - AIRCRAFT TYPES - GENERAL DATA

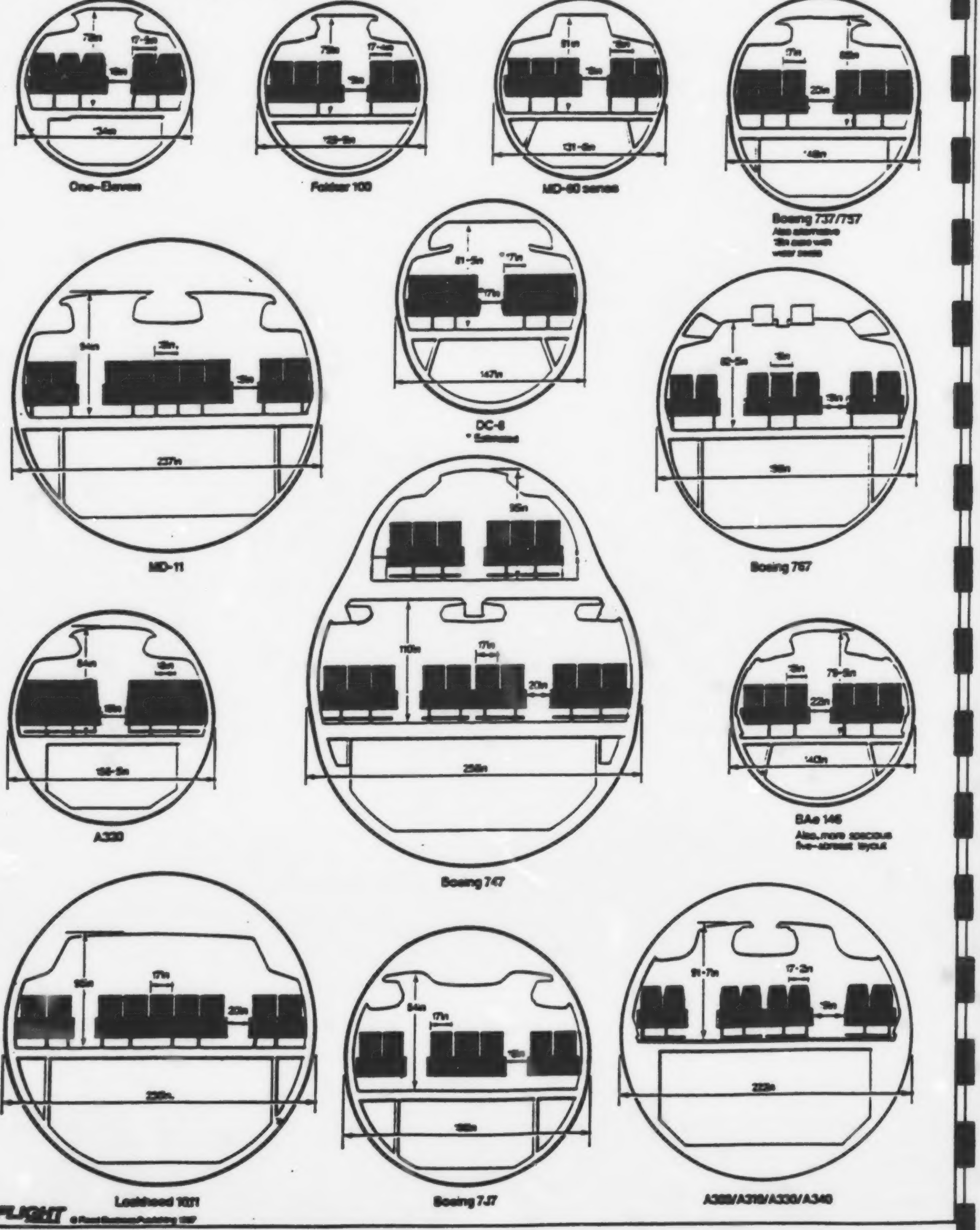
Aircraft Type	Seats Abreast(1)	Approx. Fuselage Dimensions	
		cm	in.
Bac 111	3 + 2	340	134
BAe 146	3 + 3	356	140
Fokker 100	3 + 2	330	130
MD 80	3 + 2	335	132
DC-8	3 + 3	373	147
B-737	3 + 3	376	148
B-767	2 + 3 + 2	503	198
L-1011	2 + 5 + 2	597	235
A300	3 + 3 + 3	564	222
A310	2 + 4 + 2	564	222
A320	3 + 3	396	156
A340	NA	564	222
B-747	3 + 4 + 3(2)	650	256
MD 11	2 + 5 + 2	602	237
B-757	3 + 3	376	148
B-727	3 + 3	330	130
DC-9	3 + 2	335	132
DC-10	3 + 4 + 3	602	237
DASH 8	2 + 2	249	98
DASH 7	2 + 2	279	110
ATR 42	2 + 2	287	113
SF 340	2 + 1	231	91
Fokker 50	2 + 2	249	98

(1) Typical arrangement, economy seating, standard series.
(2) Upper deck contains 3 + 3 seats abreast.

Note: The aircraft considered have maximum take-off weights in excess of 5700 kg.

FIGURE 4.7
TURBO-JET AIRCRAFT CROSS-SECTIONS - ECONOMY SEATING

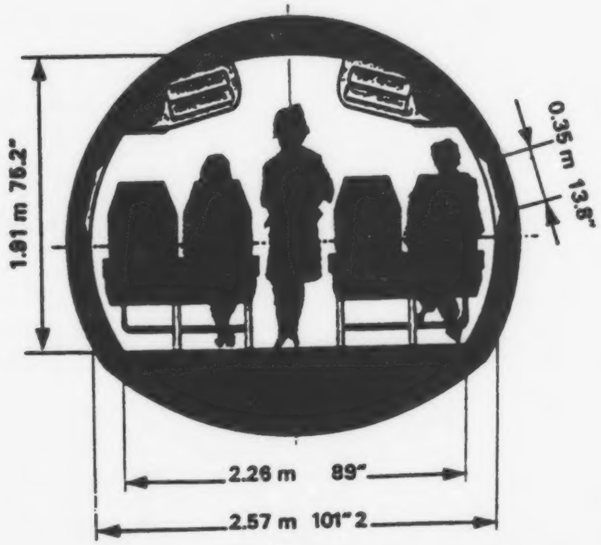
Comparative fuselage cross-sections



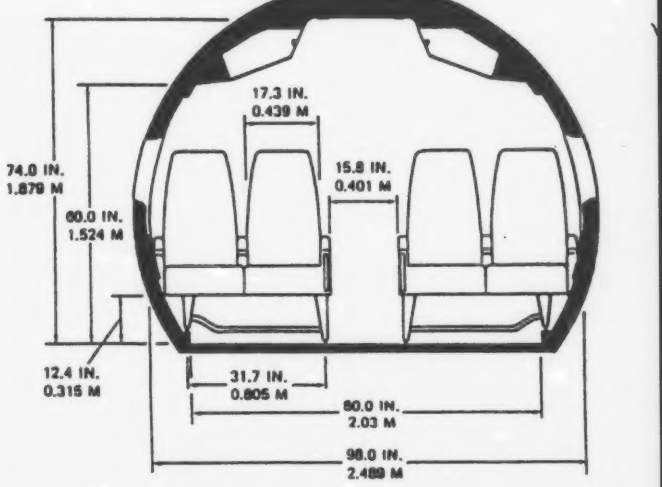
SOURCE: Flight International, October 10, 1987.

FIGURE 4.8

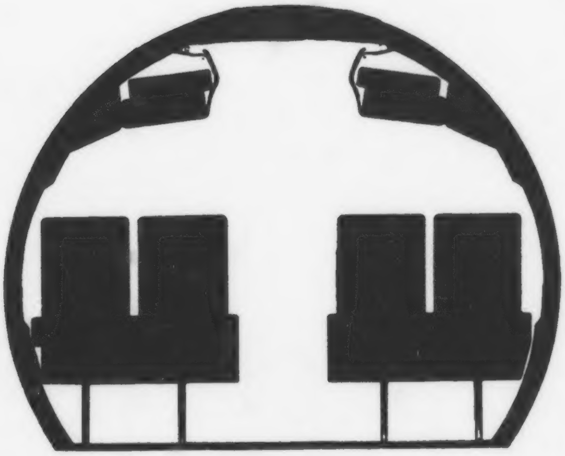
TURBO-PROP AIRCRAFT CROSS-SECTIONS - ECONOMY SEATING



ATR-42

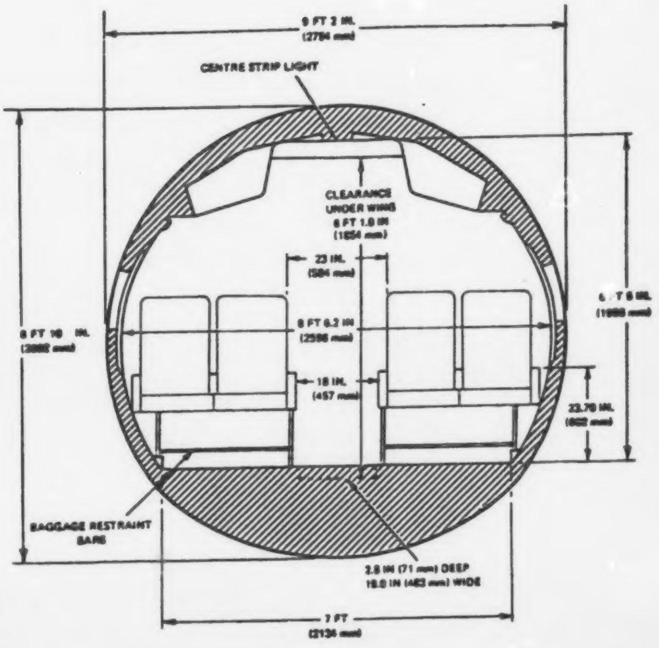


DHC-8



Dimensions			
	Maximum height	1.96 m	77.2 in
	Maximum width	2.49 m	98.0 in
	Maximum width at floor level	2.06 m	81.1 in
	Seath width	0.43 m	17.0 in
	Aisle width	0.40 m	15.9 in

FOKKER 50



DHC-7

The applicability of a design optimization for an overhead presentation and stowage scheme can therefore not be accurately related to a given aircraft type, nor a given aircraft grouping such as "wide bodied" aircraft. The same rationale applies to seat based stowage/presentation schemes. For this case, the space availability is primarily dependent on the seat type rather than the aircraft type. In fact, seat types may be identical, but the arrangement of existing equipment on the seat-back may differ.

Conceivable aircraft stowage locations as well as possible interrelationships which can be established with reasonable accuracy and validity are identified in Tables 4.3, 4.4 and 4.5. Whether the locations identified are feasible from a functional, physical and cost aspect will be the focus of subsequent sections.

Apparent limitations and constraints as applicable to the conceivable stowage locations are identified in Table 4.6 for seat based schemes, including seat-backs, seat armrests, seat headrests and seat meal-trays. The data presented in Table 4.6 is intended to reflect mean dimensions for seat characteristics such as seat pitch. The stowage schemes are strictly dependent on the seat type. In most cases, notably tourist class seats, the armrests do not have the required space available since they house the existing aircraft systems identified in Table 4.6. In some executive class seating, the armrests include stowage cabinetry and are sufficiently large as to allow for the stowage of one or several PPBE units. Meal-trays vary in stowage location and size, they are typically thin (less than 3.8 cm [1.5 inches] deep) and prone to considerable abuse. Seat headrests and seat-back stowage schemes are feasible. Seat headrest addition or replacement is viable especially where space

TABLE 4.3 - AIRCRAFT DATA - SEAT SYSTEMS

CONCEIVABLE STOWAGE LOCATIONS	GENERAL OBSERVATIONS	APPLICABILITY
Back of Seat	Seat back geometries are extremely variable. Most notably, tourist class seats versus business/executive and first class seating.	All Aircraft
Armrest Next to Seat	Seat armrest geometries are extremely variable. Most notably, tourist class seats versus business/executive class seating.	All Aircraft
Meal-Tray	Variable geometries dependent on seat types and seating discontinuities.	All Aircraft
Beneath Seat	Space availability adjacent to life vest.	All Aircraft
Headrest	This could be considered an add-on item, which may exist in limited seat types.	All Aircraft

TABLE 4.4 - AIRCRAFT DATA - OVERHEAD SYSTEMS

CONCEIVABLE STOWAGE LOCATIONS	GENERAL OBSERVATIONS	APPLICABILITY
Overhead P.S.U. panels side aisles	Most aircraft have P.S.U. enclosures at the side panel/headliner transition location. The P.S.U. enclosures commonly contain the following systems: - air gaspers and supply hoses. - ordinance signs. - seat position indicators. - reading lights. - attendant call switches. - oxygen generators. - oxygen masks and automatic dispensing container. All systems are commonly mounted on a custom design molded panel which is mounted on rails such that P.S.U. panels can be varied in pitch in congruent with seat pitch.	Space availability is not dependent on aircraft size
Overhead panels center aisles (with PSU)	As per above parameter when the interior has suspended baggage bin arrangements.	Multiple aisle aircraft with suspended baggage bins
Overhead panels center aisles (without PSU)	Between suspended overhead panels. Space provisions for: - ordinance signs. - seat position indicators. - reading lights. - oxygen generators. - oxygen masks and automatic dispensing container. All systems are commonly mounted on a custom design molded panel which is mounted on rails such that P.S.U. panels can be varied in pitch congruence with seat pitch.	Multiple aisle aircraft with no suspended baggage bins

TABLE 4.5 - AIRCRAFT DATA - MISCELLANEOUS

CONCEIVABLE STOWAGE LOCATIONS	GENERAL OBSERVATIONS	APPLICABILITY
Side Panels	Side panels have limited outboard space availability. Interference with window reveal and aircraft structure is likely.	Outboard aisles only. All aircraft models.
Galleys and wardrobes, mid cabin vanities	Modification of these aircraft systems could provide stowage space.	Occurrence is more frequent in wide body aircraft.
Partitions/ Bulkheads	Protruding stowage schemes would result.	All aircraft models.
Miscellaneous	Likely locations for passenger self stowage include: seat pouch, under armrest, floor.	All aircraft models.

TABLE 4.6 - CONSTRAINT PARAMETERS - SEAT BASED SYSTEMS

SEAT PITCH:	Seat pitch variance is primarily subject to the choice of aircraft operators rather than a limitation imposed by an aircraft model. The following seat pitches will be utilized for this study: Tourist Class(1): 84 cm (33 in.) Business/Executive Class: 99 cm (39 in.) First Class: greater than 99 cm (39 in.)
SEAT DIMENSIONS:	Seat dimensions vary considerably. Representative tourist and business/executive seat dimensions are illustrated in Figure 4.12. EXISTING SEAT SYSTEMS: The following features and subsystems may exist in typical aircraft seats: - Breakover seat back. - Foldable armrests. - Hinged meal tray in seat back. - Hinged meal tray in seat armrest. - P.S.U. panels in armrests. - Magazine pouch in seat back. - Ashtray in seat armrest. - Seat position controls in armrest. - Life vest stowage underseat. - Fireblocking system. - Oxygen system in seat backs.
DISCONTINOUS SEATING:	Seating discontinuities are defined as seat locations where systems other than seats including egress aisles occupy the space forward of the subject seat locations. Discontinuities amount to approximately 10% to 14% of total available seats for multiple aisle aircraft, and 5% to 10% for single aisle aircraft.
MAXIMUM SEATS ABREAST:	4-5 abreast seating for multiple aisle aircraft. 3 abreast seating for single aisle aircraft.

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(1) Smaller seat pitches for tourist class seats would not adversely affect conclusions.

availability in seat-backs is restricted (eg. tourist seats with existing meal-trays or existing oxygen system dispensers).

Table 4.7 presents approximate vertical distances from a deflected seat cushion to overhead panels for various aircraft models. Generally, overhead presentation schemes for existing oxygen systems are contained on the passenger service unit (PSU) panel. The PSU panels on the outboard aircraft seating locations have a 5.0 to 12.7 cm (2 to 5 inch) deep space between the panel itself and the aircraft trim sidewall or the overhead baggage bins. Inside this space are typically housed the systems highlighted in Table 4.4. The PSU panels are mounted on rails, thus allowing for variable pitch along the aircraft longitudinal axis. Overhead PSU panels for center aisles with stowage bins are analogous to the arrangement of overhead outboard stowage schemes. When there are no overhead baggage bins present, the PSU panels are located on the cabin suspended ceiling, sandwiched on either side by false trim ceilings which are used for indirect lighting. (See Section 4.2.3).

4.2.3 Detailed Interior Configuration Review

Detailed drawings and raw cost analysis data, for the principle schemes considered in Section 4.3, were gathered during the detailed configuration review. Aircraft interior details such as center and outboard PSU panels and seating arrangements, are provided for the L-1011, B-737, B-767 and B-727 aircraft in Appendix C.

TABLE 4.7 - VERTICAL AIRCRAFT INTERIOR DISTANCES

Aircraft Type	Approximate Distance Between: Deflected Seat Cushion to Overhead Bins		Pax Reach Capability	Approximate Distance Between: Deflected Seat Cushion to Center Ceiling Height		Pax Reach Capability
	cm	in.		cm	in.	
BAc-111	97 - 104	38 - 41	Yes	147 - 157	58 - 62	No
BAe-146	102 - 109	40 - 43	Yes	152 - 160	60 - 63	No
Fokker 100	97 - 104	38 - 41	Yes	150 - 160	59 - 63	No
MD-80	109 - 117	43 - 46	No	155 - 165	61 - 65	No
B-757	119 - 127	47 - 50	No	165 - 175	65 - 69	No
A320	112 - 119	44 - 47	No	163 - 173	64 - 68	No
DC-8	112 - 122	44 - 48	No	160 - 173	63 - 68	No
B-737	112 - 122	44 - 48	No	165 - 175	65 - 69	No
B-767	127 - 137	50 - 54(1)	No	160 - 168	63 - 66	No
L-1011	122 - 140	48 - 55(1)	No	193 - 201	76 - 79	No
A300	122 - 132	48 - 52	No	183 - 193	72 - 76	No
A310	122 - 132	48 - 52	No	183 - 193	72 - 76	No
A340	122 - 132	48 - 52	No	183 - 192	72 - 76	No
B-747	188 - 198	74 - 78	No	229 - 239	90 - 94	No
MD11	124 - 140	49 - 55	No	188 - 198	74 - 78	No

(1) Not applicable to centre aisle seats where overhead bins are not present.

4.3 Stowage/Presentation Schemes

The purpose of this section is to identify viable candidate stowage/presentation schemes. The viable stowage locations may vary significantly from one interior configuration to another since the existing physical interior constraints coupled with cost may or may not allow its implementation.

PPBE stowage/presentation schemes may be effectively segregated into three categories:

a) Automatic presentation designs.
b) Single action manual access/retrieval designs.
c) Simple contained stowage designs.

By "automatic presentation designs", it is intended to imply that the PPBE unit will be presented to the passengers without them necessarily having precognition of its need being required. This would assume that a crew member realizes that an emergency condition exists, and would then remotely dispense the PPBE units. Dependent on the type of PPBE unit utilized, an electrical signal or a pressure variation would be used to actuate the release mechanism in the PPBE restraining container. For an electrical system, the restraining mechanism would possibly include a solenoid, whereas a pressure switch similar to those utilized in present day oxygen presentation systems would be used for a pneumatic system. An automatic stowage presentation system would likely include the system components outlined in Table 4.8 and be very similar in design to the present oxygen overhead systems. Not all of the system components in Table 4.8 are likely to be required for any particular design.

TABLE 4.8 - AUTOMATIC STOWAGE/PRESENTATION COMPONENTS

- PPBE Units
- Activation Lanyards(1)
- Deployment Restraint Cables
- PPBE Unit Protective and Mounting Enclosures
- Release Mechanisms (Springs, Solenoid, etc.)
- Electrical Wiring or Pneumatic Tube System
- Tamper/In Use, Switches and Annunciators
- Control Panel/Activation Switches
- Annunciators
- Oxygen Supply Tubes, Manifolds and Generators or Oxygen Supply Containers(1)

(1)Not applicable to self contained PPBE units.

"Single action manual access/retrieval designs" is intended to imply that a passenger, once prompted to recognize the requirement of a PPBE unit, could, with a single hand, reach toward the stowage location, and through a single action, such as pulling or twisting, release the PPBE unit from its protective enclosure. The collection of system components used in this type of system are evidently fewer than those that are required in an automatic presentation system. These are highlighted in Table 4.9. The release mechanism may be as simple as a spring retainer. The tamper/in use annunciator, if incorporated, could be a switch designed to activate when stowed electrical contact is broken.

A "simple container stowage design" is intended to imply that the unit is simply located in a pouch or other enclosure which is not instrumented. The enclosed PPBE unit will be a self-contained type. Analogous to the other systems, a means of annunciation may be required.

Based on the study criteria, the current airworthiness and operating regulations, the PPBE specifications, the equipment manufacturer survey, the passenger reach envelopes, and the aircraft interior configuration review, ten feasible stowage/presentation schemes were identified. A definition of the schemes is provided below. Subsequent sections of the report (Section 5) will present the physical, functional and human constraints associated with each scheme, followed by decision analysis to determine viability and desirability of individual schemes.

Scheme "1" - Overhead Automatic

This scheme is analogous to that adopted by the vast majority of air carriers in providing emergency oxygen following decompression. The PPBE units would be stowed in an overhead location, possibly hidden behind a trim panel. The units

TABLE 4.9 - SINGLE ACTION MANUAL RETRIEVAL SYSTEM COMPONENTS

- PPBE Units
- PPBE Unit Protective and Mounting Enclosures
- Release Mechanism
- Tamper/In Use, Switches and Annunciators
- Cabin Crew Annunciator Activation Switches
- Annunciators
- Oxygen Supply Tubes, Manifolds and Generators or Oxygen Supply Containers(1)

(1)Not applicable to self contained PPBE units.

would drop down due to gravity and be presented within reach of the passengers when an actuation signal is received to release the restraining mechanism in the stowage enclosures.

Scheme "2" - Overhead Self-help

Analogous to scheme "1", an overhead enclosure hidden by a trim panel would house the PPBE units. The passengers would manually access and retrieve the PPBE units from their respective stowage enclosures.

Scheme "3" - Seat-Back Automatic Presentation

Some air carriers utilize this scheme to provide emergency oxygen following decompression. The seat-backs would house the PPBE units. The seat-back enclosure would be activated from a remote location to open automatically, and the PPBE units would be presented within reach of the passengers.

Scheme "4" - Seat-Back Self-Help

Analogous to Scheme "3", the seat-back would internally house the PPBE units. The passenger would access and retrieve the PPBE unit from their respective stowage enclosures located inside the seat ahead of the passenger.

Scheme "5" - Underseat Self-Help

The PPBE unit would stow under the seat ahead of the passenger, adjacent to the life vest stowage. The passenger would reach under the seat ahead and retrieve the unit.

Scheme "6" - Seat Headrest Self-Help

The PPBE unit would stow in the headrest of the seat ahead of the passenger. The passenger would reach the headrest and retrieve the unit. This scheme is essentially equivalent to the seat-back.

Scheme "7" - Seat Armrest Self-Help
The PPBE unit would stow in the armrest of the occupant's seat. The passenger would access and retrieve the PPBE unit from his/her armrest.

Scheme "8" - Meal-Tray Self-Help
The PPBE unit would stow in the meal-tray. The passenger would access and retrieve the PPBE unit from his/her seat.

Scheme "9" - Seat-Back Self-Help (external to seat)
The PPBE unit would be located in an external pouch or enclosure on the seat-back. The passenger would access the PPBE unit from the external pouch located in the seat ahead of him or her.

Scheme "10" - Passenger Self-Help Carry-On
Each passenger would be provided a PPBE unit upon entry to the aircraft. The subsequent stowage location is determined by the passenger.

Scheme "6" is essentially identical to Scheme "4", since the headrest is merely an extension of the seat-back. Both schemes will henceforth be referred to as: seat-back self-help (flush with seat back). Scheme "9" differs from the above scheme in that the PPBE is housed in an external envelope. This scheme will be henceforth referred to as: seat-back self-help (external pouch or pocket).

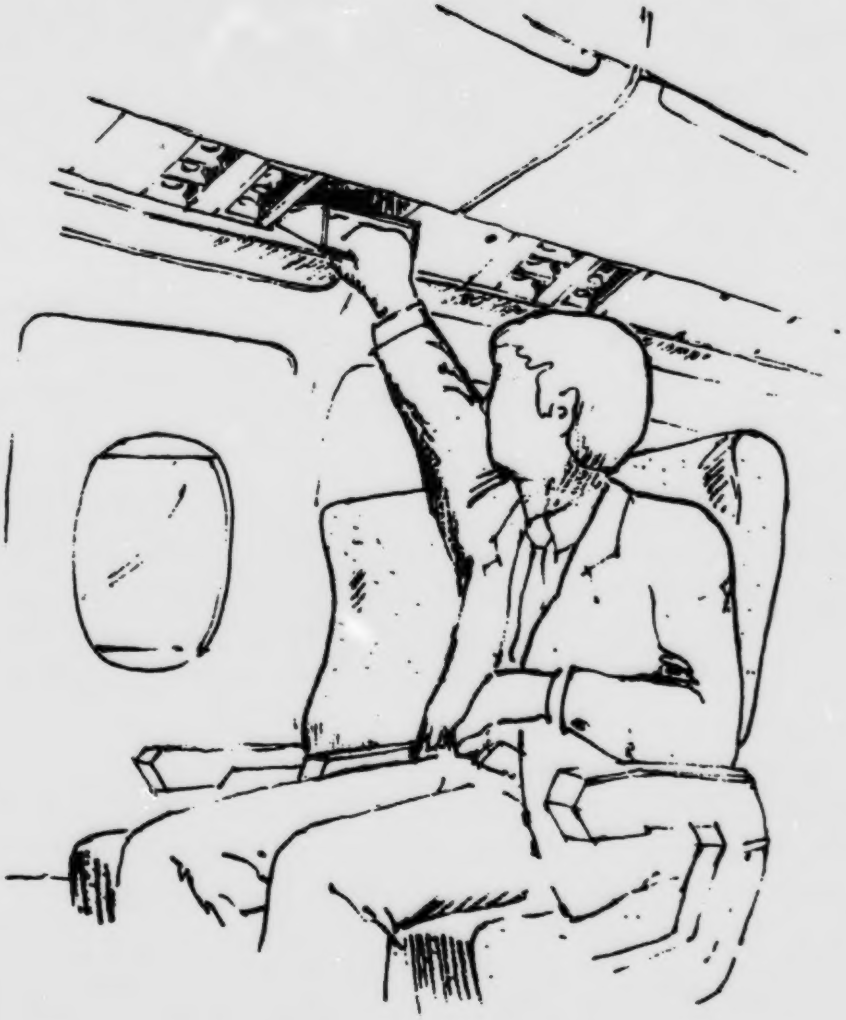
For PPBE unit stowage/presentation at discontinuous seating locations, the nature of physical and functional constraints are likely to change. The differing constraints would compel a variant of the above listed schemes to be implemented.

There is no single scheme recommended for installation at seating discontinuities and each must be considered separately. An overhead presentation scheme may be appropriate when facing a bulkhead with no forward seats available, however, if the discontinuity is due to an exit aisle, the overhead presentation scheme may become a hazard and thus highly undesirable. Table 5.3 of Section 5.2.4 lists discontinuous seating examples and identifies associated constraints.

Renderings of various PPBE stowage/presentation schemes are included in Sketches 4.1 through 4.3.

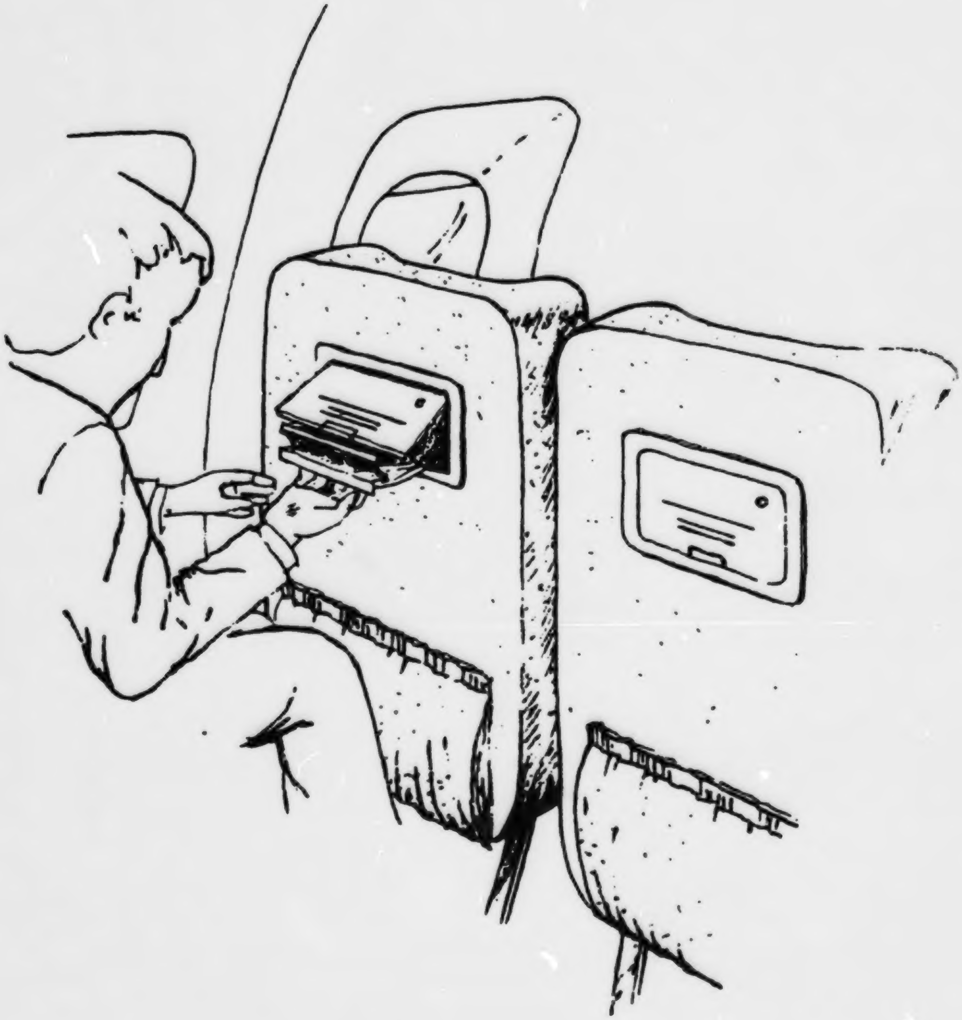
SKETCH 4.1

RENDERING OF OVERHEAD SELF-HELP SCHEME



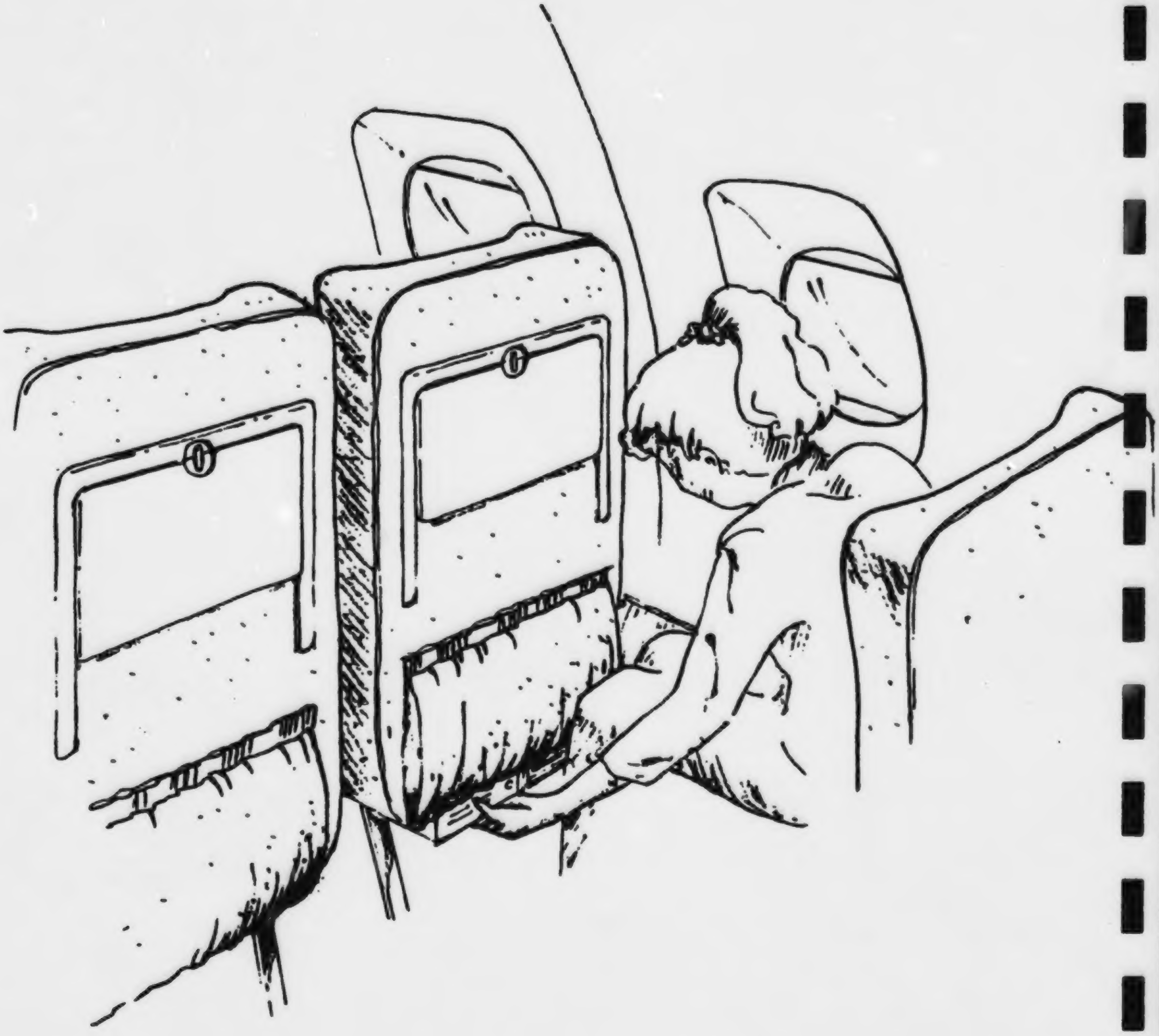
SKETCH 4.2

RENDERING OF SEAT-BACK SELF-HELP SCHEME



SKETCH 4.3

RENDERING OF UNDERSEAT SELF-HELP SCHEME



5. FUNCTIONAL CONSTRAINTS, PHYSICAL CONSTRAINTS AND HUMAN FACTORS

This section of the report discusses the functional and physical constraints as well as the human factor issues. Functional constraints are restrictions which prevent the use of PPBE and include considerations such as damage. Physical constraints, on the other hand, are restrictions which relate to the stowage enclosure, and may include restrictions caused by equipment such as PSU panels. In order to allow for a more comprehensive assessment of PPBE, human behaviour considerations are also discussed at the end of this section.

5.1 Functional Constraints

Design boundary conditions which manifest themselves as functional restrictions with respect to proposed PPBE stowage/presentation are termed "functional constraints" or "functional boundary conditions".

Functional constraints are associated with differing operations, procedures and scenarios. Partitioning of these considerations will lead to functional constraints being easily identified.

5.1.1 Emergency Scenario Exclusivity

It has not as yet been conclusively established whether PPBE should address hypoxia considerations. Certainly, the functional constraints will differ for a combined smoke/hypoxia system. Listed below are a few emergency scenarios which would warrant combined smoke/hypoxia protection.

- If a sudden decompression at altitude followed by immediate smoke and fire is considered a valid emergency scenario, then the PPBE should be of a combined smoke/hypoxia design.

- If fire and smoke followed by a sudden decompression at altitude is considered a valid emergency scenario, then the PPBE should be of a combined smoke/hypoxia design.

- If emergency evacuation is required following a smoke/hypoxia scenario, then the PPBE must be of a design which allows for an additional five minutes of self-contained usage.

The S.A.E. A-10, AS 8048 PPBE draft specification dated December 2, 1987 and the C.A.A. PPBE specification dated February 26, 1988 do not require PPBE to provide simultaneous protection against both decompression and fire. However, a proviso is included in the specification which requires that equipment designed to provide simultaneous protection against decompression and cabin fire would have to satisfy the applicable requirements of JAR 25.1441.

Should a PPBE unit be of a combined smoke-fire/hypoxia design, then the following may be applicable:

- The stowage/presentation requirements default to those of existing aircraft oxygen systems.
- An automatic presentation system would be mandatory.
- The ten second recognition to usage regulation for hypoxia systems would have to be satisfied.
- The activation for presentation would be automatic activation via a pressure transducer, with manual override.

- A means would be required to free the mask quickly from the aircraft oxygen supply while ensuring positive connection for hypoxia situations.

It is noteworthy that automatic presentation of emergency oxygen systems is only required for operation above 30,000 feet. The ten second recognition to use requirement for PPBE must nevertheless be respected.

None of the prototype PPBE units examined in this report address combined fire/hypoxia protection, however, it is understood that this type of unit is being developed. The combined smoke/hypoxia PPBE scheme will therefore be included in the analysis in Sections 6 and 7.

5.1.2 Pilferage, Tampering and Damage

Potential pilferage of PPBE can result in both a large capital loss, and a safety infringement. One air carrier estimates that up to 30 per cent of the flotation devices installed under aircraft seats are pilfered each year. The costs associated with replacing and reinstalling the units can therefore be quite substantial. Since checking on these components is performed once per flight cycle, not all stowage locations may contain a unit on the return flight. The probability of tampering and damage will likely increase for self-help systems, especially if these systems are located within the optimum visual cone. Meal-tray based schemes, for example, may be prone to excessive tampering, abuse, and damage due to fluid spillage.

5.1.3 Emergency Recognition and Deployment Cycle

The period of time between the instant that an emergency condition necessitating the need of PPBE is recognized, to the instant that the PPBE is deployed or the passengers are notified to access the PPBE, is henceforth referred to as the "emergency recognition and deployment cycle".

A considerable amount of discussion has been associated with whether the emergency condition requiring PPBE is more readily recognized by individual passengers or the cabin crew. This consideration affects the degree of desirability associated with passenger self-help versus automatic presentation schemes.

A single case accident report is commonly cited to highlight that passenger self-help schemes may be preferable to cabin crew deployment control. One may not conclusively adopt this functional philosophy based on a single statistic. A brief examination of the process of events which are likely to occur during an emergency recognition and deployment cycle is given below:

TIME	EVENT
t0 = 0.0	Local passenger recognition of emergency condition.
t1 = t0 + INCR.1.	Cabin crew recognition of emergency condition.
t2 = t1 + INCR.2.	Cabin crew PPBE deployment or annunciation.
t3 = t2 + INCR.3.	Global passenger recognition of emergency condition.
t4 = INCR.1. + INCR.2.	

+ INCR.3. End of emergency recognition and deployment cycle.

Assuming that some passengers local to the emergency recognize the emergency prior to cabin crew members, and that passengers are aware of how to proceed, they can exit the emergency recognition cycle immediately by initiating the access/retrieval cycle. Conversely, the cabin crew may recognize the existence of an emergency before any passenger, especially if the smoke/fire source is remote to the immediate passenger seating area. Also, the cabin crew may recognize the emergency condition at the same time as any passenger, or be immediately informed by a passenger(s). Time increment '1' would then approach zero.

Time increment '2' will be dependent on the location of crew members in the cabin at emergency recognition. Should the cabin crew be located at the cabin crew station where deployment/annunciation controls are likely to be located, time increment '2' will be minimal. The time required by a single crew member to reach the deployment/annunciation controls from the most remote location in the aircraft cabin will establish a maximum for time increment '2'.

Time increment '3' is dependent on the nature of the annunciation and subsequent passenger behaviour. Without global annunciation, time increment '3' may be very large indeed. It is evident that in order to minimize the time required for the majority of passengers to begin the PPBE retrieval stage, time increment '3' must be minimized, ie., some form of global annunciation is required.

A self-help system may ultimately reduce the emergency recognition and deployment cycle time required for a very few passengers, however for the majority of passengers, the self-help scheme will not reduce the cycle time since crew action is required for global annunciation. Furthermore, some passengers may not recognize the emergency since they may be far removed from the emergency area, sleeping, or otherwise distracted. Therefore, the remote deployment of PPBE in the cabin is considered to be a cabin crew responsibility.

5.1.4 Passenger Reach Envelopes

Functional constraints associated with the reach envelopes are as follows:

1) Passengers are considered as belted into their respective seating locations.

2) Passengers stranded in aisles are considered as mobile. Mobile passengers are considered as having extremely large reach envelopes, ie. with a single step, the mobile passenger can effectively increase his reach envelope to more then twice that of a seated passenger.

3) Self-help stowed units must be within reach of seated passengers.

4) Presentation units must be within reach of seated passengers.

5) Passengers smaller than military standard 5 percentile[1] women or impaired passengers are considered to require crew cabin, or fellow passenger aid if cabin crew are not able to provide aid.

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[1] May be precluded by PPBE specifications ultimately requiring a 2 percentile lower limit.

Self-help type stowage locations which are outside the passenger reach envelopes are unacceptable.

5.1.5 Compatibility With Existing Systems

The implementation of PPBE systems should not degrade the functionality of existing aircraft systems. Some considerations include:

- Aircraft oxygen systems.
- Access to existing emergency items such as life vests and fire extinguishers.
- Aircraft electrical loads.
- Seat breakover backs and armrests.
- Seat fireblocking systems.

As an example, the deployment of existing oxygen masks should not be compromised. Furthermore, the oxygen supply should not be compromised due to possible increased oxygen demand, and contamination of oxygen system components must be avoided during retrofit and service of PPBE In order to retain this compatibility, additional engineering, service and maintenance costs will be incurred.

5.1.6 Cabin Crew Tasking

Ideally, the PPBE system installation design should be optimized such as to minimize crew tasking. During regular operations, the time required to ensure the operative status of the PPBE in the stowed location and provide passenger briefing should be minimized. Crew tasking should most notably be minimized during emergency scenarios. PPBE cabin crew controls, if required, should be located such as to minimize cabin crew access time to these controls in the event of an emergency. Once the required annunciation and or deployment has been realized, individual passengers may require assistance. The cabin field of vision allowed to the cabin crew should therefore be optimized. Presentation features, such as deployed PPBE hanging overhead, would allow cabin crew to readily confirm the deployed status of individual PPBE units.

During an emergency scenario, cabin crew are tasked with a variety of procedures. They are normally located at their respective stations to implement the majority of these procedures. The cabin crew stations are usually judiciously placed in the aircraft to optimize the monitoring of events and passengers, particularly during take-off and landing. They are also designated to cabin crew seating positions. It would therefore be appropriate to locate any required PPBE controls in close proximity to the cabin crew stations of subject aircraft. This methodology will be flawed should crew stations not be located at 'optimum' locations. It would therefore be necessary to review individual interior arrangements to ensure that the intent of the recommendations are realized. Circumstrances under which cabin attendents might provide aid are probably limited to in-flight situations.

5.1.7 Donning

The method used for prompting passengers to utilize the PPBE should be optimized. Visual and/or aural annunciation should be unambiguous, comprehensible and perceptible to every passenger.

Once passengers have identified the PPBE unit location, the access and retrieval should be evident. Visual prompting may be required dependent on the stowage/presentation scheme. The February 26, 1988 C.A.A. PPBE draft specification dictates that "The equipment, as installed, shall be capable of being put into effective use by the wearer within ten seconds of its need being recognized. This time shall include the time taken to remove the equipment from its stowage.". Also, "where the effective life of the equipment is dependent upon storage in an hermetically sealed valise, or equivalent, release from such a valise shall be concurrent with the removal of the equipment from its stowage and shall not require any separate secondary action. This requirement shall apply even where the equipment is automatically presented to the passenger." In view of the time and functional constraints above, it is clear that the stowage/presentation design should not present difficulty or undue dexterity requirements to the passenger. The PPBE stowage/presentation scheme should be designed such as to minimize that portion of the 10 second time constraint required to access the unit. It was identified that a PPBE scheme which requires the user to 'plug in' his PPBE unit into a remote oxygen supply is unacceptable - this is justified by the specification requirements.

5.1.8 Post Deployment/Donning

Following deployment and donning of the PPBE units, it would be undesirable for any part of the PPBE system to impede mobility through aircraft aisles and seat rows. PPBE installation schemes such as meal-tray may prove undesirable in this respect since it is probable that meal-trays will be left deployed. A meal-tray based PPBE design should therefore not result in the meal-tray itself being deployed. Similarly, overhead systems should not deploy over aisles or cross-aisles where they are likely to impede subsequent passenger egress. Presentation systems should minimize subsequent visual and physical interference, which they may possibly present to exiting passengers. If the PPBE system is dependent on a remote oxygen supply or the aircraft oxygen/hypoxia system, the stowage/presentation considerations must ensure successful disengagement from the parent system when required.

Table 5.1 presents the functional constraints identified above in compact format.

TABLE 5.1 - FUNCTIONAL CONSTRAINT CONSIDERATIONS - SUMMARY

Stowage/Presentation Scheme	Functional Constraint Considerations
Overhead Automatic Presentation	- Satisfactory for combined smoke/hypoxia PPBE units. - Desirable W.R.T.(1) tampering, pilferage and damage. - Global emergency recognition and deployment time is minimized. - Passenger reach envelope requirements may be optimally satisfied. - Functional compatibility with existing system can be satisfied. - Minimizes crew tasking. - Minimizes global donning time. - Satisfactory W.R.T. post deployment constraint considerations.
Overhead Self-Help	- Unsatisfactory for combined smoke/hypoxia PPBE units (see Section 5.1.1). - May be satisfactory W.R.T. tampering, pilferage and damage. - Global emergency recognition and deployment time is unknown. - Passenger reach envelope requirements may not be satisfied. - Functional compatibility with existing systems can be satisfied. - Will not minimize crew tasking. - Will not minimize global donning time. - Satisfactory W.R.T. post deployment constraint considerations.
Sidewall Self-Help	- Unsatisfactory for combined smoke/hypoxia PPBE units. - Undesirable W.R.T. tampering, pilferage and damage. - Global emergency recognition and deployment time is unknown. - Passenger reach envelope requirements may not be satisfied. - Functional compatibility with existing systems can be satisfied. - Will not minimize crew tasking. - Will not minimize global donning time. - Satisfactory W.R.T. post deployment constraint considerations.

(1) W.R.T. = With respect to.

TABLE 5.1 Continued

Seat-Back Automatic Presentation	- Satisfactory for combined smoke/hypoxia PPBE units. - Desirable W.R.T. tampering, pilferage and damage. - Global emergency recognition and deployment time is minimized. - Passenger reach envelope requirements may be easily satisfied. - Functional compatibility with existing systems can be satisfied. - Minimizes crew tasking. - Satisfactory W.R.T. post deployment constraint considerations.
Seat-Back Self-Help	- Unsatisfactory for combined smoke/ hypoxia PPBE units (see Section 5.1.1). - Undesirable W.R.T. tampering, pilferage and damage. - Global emergency recognition and deployment time is unknown. - Passengers reach envelope requirements may be easily satisfied. - Functional compatibility with existing systems can be satisfied. - Will not minimize crew tasking. - Will not minimize global donning time. - Satisfactory W.R.T. post deployment constraint considerations.
Seat Armrest and Meal-tray Self-Help	- Unsatisfactory for combined smoke/ hypoxia PPBE units. - Very undesirable W.R.T. tampering, pilferage and damage. Inadvertent damage probability may increase. - Global emergency recognition and deployment time is unknown. - Passenger reach envelope requirements may be satisfied. - Functional compatibility with existing systems can be satisfied. - Will not minimize crew tasking. - Will not minimize global donning time. - Undesirable post deployment constraint considerations.

TABLE 5.1 Continued

Under-Seat Self-Help	- Unsatisfactory for combined smoke/ hypoxia PPBE units. - Undesirable W.R.T. tampering, pilferage and damage, inadvertent damage probability may increase. - Global emergency recognition and deployment time is not known. - Passenger reach envelopes requirements may be satisfied. - Functional compatibility with existing systems can be satisfied. - Will not minimize crew tasking. - Will not minimize global donning time. - Satisfactory post deployment constraint considerations.
Carry-On Self-Help	- Unsatisfactory for combined smoke/ hypoxia PPBE units. - Tampering, pilferage and damage are increased considerably. Inadvertent damage probability may increase considerably. - Global emergency recognition and deployment time is unknown. - Passenger reach envelopes requirements may be unsatisfactory. - Functional compatibility with existing systems can be satisfied. - Will not minimize crew tasking. - Will not minimize global donning time. - Satisfactory post deployment constraint considerations.

5.2 Physical Constraints

Design/implementation conditions which manifest themselves as undesirable physical restrictions with respect to proposed PPBE stowage/presentation schemes are defined as 'physical constraints'.

The design requirements of the PPBE stowage enclosure must provide suitable protection to the unit itself, such that the protection afforded to the PPBE system as a whole is suitably satisfied. The nature and extent of the protection afforded by the stowage enclosure is dependent on the additional protection required for any subject PPBE unit. No viable PPBE nor PPBE unit data to allow evaluation of additional protection scheme requirements is available at present. The system protection requirements specified in the C.A.A. specification (see Table 3.1) include paragraph numbers 3.17.2, 6.1, 6.2, 6.3, 6.4 and 6.5.

It is required that the serviceability of the PPBE be readily determined. Again, this is very dependent on the nature of the PPBE itself. If, for example, leakage occurs in the PPBE, a chemically induced colour change to a 'window' on the PPBE package might be engineered. The containment assembly should therefore not degrade this feature.

It is required that a means be provided to allow the passenger to access his/her PPBE in case of an automatic deployment failure. Current oxygen hypoxia systems must also satisfy this requirement. The means of providing for such a feature would be very similar.

The physical constraints will differ with the aircraft interior configurations. Data established in Section 4 will be used to justifiably generalize the aircraft interior configurations while identifying the physical constraints. Table 5.2 presents a general summary of physical constraints for the stowage/presentation schemes. Each of the schemes are subsequently discussed in greater detail.

5.2.1 Overhead Systems

Inspection of the data presented in Table 5.2 and the reach envelope (see Figure 4.5) indicate that for most aircraft configurations examined, the overhead stowage schemes must default to the automatic presentation type since the stowage locations exceed the allowable limit of the reach envelopes. Excluding the additional space requirement for the deployment mechanism of an overhead automatic presentation system, the physical constraints associated with a self-help overhead system are similar. These constraints include:

- Existing space availability in overhead PSU panels.
- Possible interference from existing systems, ie. overhead oxygen/hypoxia, canisters stowage, supply lines and wiring.
- Overhead ducting.
- Overhead bins.
- Overhead support structure.
- Headliner and trim panel geometry.

The space availability for PPBE stowage is further reduced by minimum clearance requirements associated with wiring, supply lines and high heat generating chemical oxygen canisters.

The overhead areas of the outboard seating aisles are considered separate from the locations over the center seating aisles since here too, the constraints vary significantly.

TABLE 5.2 SUMMARY OF PHYSICAL CONSTRAINTS ASSOCIATED WITH STOWAGE/PRESENTATION SCHEMES

Stowage/Presentation	Physical Constraints
Overhead Self-Help	- The scheme is not viable for most aircraft types and configurations since passenger reach envelopes are exceeded. - Extensive modifications are required to the overhead P.S.U. panels and existing overhead systems.
Overhead Automatic Presentation	- Replacement of existing overhead P.S.U. panels for most aircraft. - Modifications required to existing overhead systems. - Possible modification requirements to the baggage bin systems for some interior configurations. - Possible modification requirements to headliner/suspended ceiling for wide-body aircraft. - Removal of interior headliner/sidewall may be required to locate control wiring.
Seat-Back Automatic Presentation	- Existing hypoxia system preclude installation of a seperate PPBE in some seat types. - Modifications to mealtray and other existing systems on the seat-back is required for some seat types. - Control wiring to seats is required. - For non-self contained PPBE, oxygen supply defaults to chemical cannister source. - Alternate stowage scheme required at discontinuous seating locations. - Protection from tampering and pilferage required for stowage design.

TABLE 5.2 Continued

Seat-Back Self-Help	- Existing hypoxia system preclude installation of a seperate PPBE for some seat types. - Modifications to mealtray and other existing systems on the seat-back required for some seat types. - For non-self contained PPBE, oxygen supply defaults to chemical cannister source. - Alternate stowage scheme required at discontinuous seating locations. - Protection from tampering and pilferage required for stowage design.
Under-Seat Self-Help	- Footrest modification required for some seat types. - Slight relocation of life vest stowage may be required. - Protection from tampering and pilferage required for stowage design.
Seat Pouch Self-Help	- Protection from tampering, pilferage, aircraft flight loads and damage required of stowage design but, notably very difficult to realize.
Sidewall Self-Help	- Reach envelopes are exceeded for three abreast seating, and non-optimal location for two abreast seating. - Stowage space availability is limited.
Passenger Carry-On	- Acceptable stowage locations are limited to person, magazine pouch of facing seat, resulting in severe functional constraints. - No stowage protection afforded from tampering, pilferage, aircraft flight loads or damage.
Seat Armrest and Mealtray Self-Help	- Severe space limitations for many seat types. - Relocation of existing armrest systems may be required. - Protection from tampering, pilferage and damage required, but, notably difficult to realize.

Outboard aisles seating:

The overhead geometry of the outboard seating aisles is defined by the outboard sidewall's contour/PSU panel and baggage bin shape. Examining the passenger reach envelopes and the figures in Appendix C, it is evident that the PSU panel area and/or the area directly under the baggage bins are the only reasonable overhead locations for installing PPBE This statement may be qualified by simply noting the following considerations:

- Modifications outside the areas occupied by the PSU panels would require significant redesign of the headliner or baggage bin system (major refurbishment requirements).

- There are space restrictions and interference outboard of the side panels due to window assemblies and reveals, exits, aircraft structure, thermal and acoustic insulation.

- Aisle interference can be caused by drop-down systems which originate inboard of the baggage bins (functional boundary condition).

The figures in Appendix C present detailed dimensional data of existing PSU panels. It is easily verified by examining the PPBE size envelopes (Table 2.3), that the PPBE units could not be housed in the existing PSU panels without modification to the PSU panels themselves, and, in some cases, the baggage bins. The PSU panels are manufactured from mold injected plastic specifically designed to mount and house the equipment summarized in Table 4.4. This equipment can not be relocated to allow the desired space for PPBE stowage. IF PPBE is to be installed in the PSU panels, it would be necessary to replace the existing shipset of PSU panels by new panels specifically designed also to house the additional equipment. In some cases, replacement of the existing PSU panels by custom designed replacement PSU panels will not be the only modification required to secure necessary space. The bottom of the baggage bin base may have to be raised to allow sufficient depth to accept the PPBE stowage enclosure.

Center aisles seating:

The overhead geometry of the center seating aisles is defined by the headliner and suspended ceiling shape or suspended baggage bin arrangement shape. Examining Figures 4.9 through 4.16, the PSU panels are either located in-between suspended ceilings, immediately outboard of the suspended ceiling or between suspended baggage bins. Comparing the reach envelopes and the above drawings, the following observations are made: the existing PSU locations, the underside of baggage bins, and ceiling panels are all feasible areas for which to install PPBE The two latter locations are considerably less desirable since the carry-on baggage space allowance is reduced for one scheme, and significant redesign and modification of the suspended ceiling would be required for the other. Once again, it is verified by examining the PPBE size envelopes and Figures 4.9 through 4.16 that the PPBE units could not be housed in the existing PSU panels without modification to the PSU panels themselves. For the same reasons presented previously, it is therefore necessary to completely replace the shipset of PSU panels by new PSU panels specifically designed to house the existing equipment and the additional PPBE equipment. Although it is noted that modification of the surrounding suspended ceiling to allow for greater inboard/outboard space would be generally undesirable, an absolute assertion is not intended.

There may be interior arrangements which lend themselves favourably to modifications of the ceiling panels as opposed the the PSU panels. For these cases the complexity associated with the modification is not likely to be reduced substantially. For analysis purposes, it would be tolerable to treat these two types of modifications as equivalent. The allowable radial expansion at PSU panel locations is generally not as restrictive as it was for the outboard aisle PSU panels. Even so, some interior configurations may not require just the replacement of the existing PSU panels, but additionally, modification of the surrounding suspended ceiling to secure sufficient space.

To summarize, feasible retrofit schemes to incorporate PPBE in overhead locations, for most transport category aircraft, are limited due to the implementation difficulties likely to be incurred. The most viable scheme identified is a complete replacement of the shipset of PSU panels with a new shipset designed to accommodate PPBE. Whether this approach is feasible for all aircraft interior configurations cannot be confirmed without an exhaustive engineering feasibility analysis particular to the subject aircraft. The following considerations would certainly need to be addressed:

- Location requirements for PPBE annunciation to don equipment.

- Structural compliance of interior modification.

- Additional wiring requirements.

- Safety precautions with respect to existing oxygen supply lines/cannisters, wiring and Electro-Magnetic Interference (E.M.I.).

- Power supply requirements.
- Interference with miscellaneous ducting, thermal/ acoustic insulation, frames etc...
- Interior baggage bin volume requirements.

If the overhead PPBE scheme were to be implemented at a time when the aircraft was scheduled for a complete interior refurbishment or major airframe inspection requiring the interior to be removed, the costs associated with implementing this scheme would certainly be reduced.

5.2.2 Seat-Back Systems

Data presented in Figure 4.3 and Figure 4.5 shows that unless the seat pitch exceeds 40 inches, seat-back systems may be either self-help or automatic presentation types. There are no absolute functional constraints which invalidate this conclusion. The physical constraints associated with seat-back schemes may include:

- foldable food trays
- magazine pouches
- fireblocked systems (seat cushions)
- wire routing
- seat pitch
- existing hypoxia system
- seat structure

These items/systems may or may not be present in any given seat type.

5.2.2.1 Seat-Back Automatic Presentation System

The PPBE seat-back automatic presentation system would likely be similar to the hypoxia system installations found on some aircraft seats in use by commercial carriers. As previously noted, space availability in the seat-back is dependent on which systems are present. The greater the number of existing systems located on or in the seat-back, the more complex the required modifications become. If the seat-back were to contain a hypoxia system, the modification difficulties would be sizable, thus the seat-back scheme may not be warranted. In the majority of tourist class seats, the meal-tray would pose the most unfavourable constraint. The meal-tray could be replaced or modified such that space requirements for the PPBE is satisfied. However, the extent of modification is once again completely variable since it is dependent on the individual seat type considered. Some seats do not house meal-trays, notably first class seats. The required modifications would then reduce to rework of the seat-back ensuring the seat structure is not compromised. Since all seats are fireblocked, the installation of a PPBE unit in the seat-back must not degrade the integrity of the seat cushion with respect to fireblocking. Should the PPBE unit not be self-contained, the seat-back scheme may be unfavourable since additionally, a thermally shielded chemical oxygen generator would have to be incorporated in the seat-back. A gaseous aircraft oxygen supply to individual seating locations is not viable.

5.2.2.2 Seat-Back Self-Help (Flush with Seat-back)

The constraints associated with this scheme is similar to the automatic presentation system discussed. The obvious difference is that this self-help system is likely to occupy less space and not require a control system ie., electrical wires, to pass through the seat. A large percentage of seats do not incorporate headrests, the incorporation of seat headrests solely to occupy PPBE although viable, may have aesthetic drawbacks. The passenger visual envelope may also be unacceptably restricted (safety concern).

5.2.2.3 Underseat Self-Help

By examining the reach envelope plot of Figure 4.5 it can be concluded that stowage of a self-help PPBE under the immediate forward facing seat, see Sketch 4.3, is permissible. The physical constraints associated with such a system are few. Footrests and existing life vests may present some interference, but in seat types where space is limited, the life vest stowage can be displaced slightly, and the footrest modified. Most passengers tend to utilize the space under the forward seat for stowing carry-on baggage. The manner in which this baggage is placed under the seat is not always courteous, this problem can be addressed through PPBE enclosure design.

5.2.2.4 Seat-Back Self-Help (External Pouch or Pocket)

A seat pouch which attaches to an available area on the seat-back would require minimal modifications to the seat itself. Perhaps the most notable constraint associated with such a scheme is the level of pilferage, tampering and damage protection which can be implemented into the design of the stowage enclosure. The PPBE must also be restrained with respect to aircraft loads.

5.2.2.5 Seat Armrest and Meal-Tray Self-Help

Substantial modifications, due to space limitations, would be required to house the PPBE units within the seat armrest or the meal-tray. Protection from tampering, pilferage and damage would be required, and may be difficult to realize.

5.2.3 Passenger Carry-On

There are no viable locations for the passenger to stow his/her PPBE unit, except for the existing magazine pouch on the immediate forward seat. This location is possibly overutilized already and may be deleterious to the pouch itself. Due to the lack of possible stowage locations available to the passenger, the resulting functional constraints make this scheme highly undesirable. Additionally, all items of mass must be secured (Air Regulation 218 and ANO SR vii, No. 4). This parameter may be difficult to satisfy by the air carrier.

5.2.4 Discontinuous Seating Locations

The functional and physical constraints summarized in previous sections are also applicable to discontinuous seating locations.

The type of stowage/presentation scheme selected should address and satisfy the particular constraints associated with the particular discontinuity. These are summarized in Table 5.3.

TABLE 5.3
CONSTRAINTS - SEATING AT DISCONTINUITIES

Type of Seating Discontinuity	Boundary Constraints
Seats facing an egress aisle:	- Presentation/Stowage scheme should not obstruct or interfere with aircraft evacuation.
Seats facing bulkhead or partition:	- Presentation/Stowage scheme should not degrade structural integrity of bulkhead or partition.
Seats facing galleys and water closets:	- Presentation/Stowage scheme should not degrade structural integrity of unit, nor should characteristic local environmental conditions of these units adversly affect the PPBE.
Flight Attendant specialty seats	- These seats usually mount onto bulkheads or partitions. or in other instances, these may be free standing floor mounted units. A special PPBE may be required for crew protection.

5.3 Human Factors in Stowage and Presentation of PPBE's

5.3.1 Stowage Considerations

The human factors and human behaviour considerations regarding stowage involve monitoring, inspection, and maintenance by airline staff, and possibilities for misuse by passengers. The passengers should interact with the devices only when they are presented, therefore any contact with the devices when they are stowed constitutes misuse.

5.3.1.1 Crew Inspection

The stowed PPBE devices must be inspected to ensure that they are all in place and likely to be in working order. If this inspection is required only once per day, human factor requirements for fast, easy, reliable inspection can be eased to some degree. However, if the devices must be checked prior to every flight, or even monitored at other points before all passengers have de-planed, an easy to use system is required.

The inspection should be by visual means and should be "feature positive". It is easier to detect a problem in a unit if the problem signal is in the "on" state. For example, if a blue signal light was used, the crew should look for a blue light "on" to signal a problem rather then trying to tell which of the many blue lights was not "on". This is in line with the requirement that the "indication should be such as to attract the cabin attendants' attention without the necessity of a unit inspection". The signal should be within the normal field of view of cabin attendants as they walk up or down the aisles.

A major requirement of the Statement of Work (SOW) regarding inspection is that the stowage system must clearly indicate if the device has been tampered with. This could be accomplished by means of a separate alarm for each device, a central control panel indicating the status of each device, or other special mechanisms. However, the additional costs and potential for false alarms probably make a special "tamper alarm" unfeasible. The primary system for inspections should also be made to reliably indicate if any tampering has taken place.

5.3.1.2 Maintenance

Maintenance includes regularly scheduled ground inspections of the devices, checks of system integrity, replacement of activated devices, replacement of devices at the end of their life-cycle, and preventive maintenance. To the extent possible, these maintenance activities should be:

- the same for different aircraft within a carrier's fleet,
- documented clearly in terms of procedures and signed confirmation,
- easy to perform, and
- effective in ensuring maximum device reliability for the entire life-cycle.

5.3.1.3 Pilferage and Damage

Possibilities for passenger misuse during stowage include the following:

a) **Pilferage**

The SOW states that the stowage concepts should discourage pilferage. Frequent loss of devices due to theft would be a major cost burden in terms of unit cost, maintenance, and legal involvement.

Two main concepts are presented in the SOW. In the first, "access to the equipment is controlled by the passenger". This method is more likely to lead to pilferage unless additional measures (other than those required for inspection) are taken to indicate when each unit is in its proper stowed position. In combination with certain stowage locations (seat-back pouch, armrest, meal-tray) this concept would almost encourage attempts at pilferage.

Regardless of the location or stowage concept, passengers should be provided with a warning (eg. "Theft or misuse of this emergency equipment is a serious crime which could lead to a fine and imprisonment. An alarm will automatically show the cabin attendants if you try"). This will discourage most passengers from pilferage, intentional damage, and use at an improper time.

For those who are especially determined to try to steal one or more devices, for those who can bypass the automatic indicators, or for the stowage/presentation scheme where the passengers are given the devices and expected to return them upon safe landing, an exit alarm detector may be necessary.

b) Unintentional Damage

According to the SOW the location and design of the stowage should minimize the possibility of damage. Operators of all modes of transport know that whatever can be broken may be broken at some time. Passengers may,

- lay on meal-trays to sleep,
- try to force large and/or hard objects underseat, into baggage bins and into seat-back pockets,
- stand on seats or armrests,
- try to force controls that do not immediately produce the desired effects, and
- otherwise exert tremendous pressures on various surfaces through a combination of contact and weight or isometric muscle force.

Compliance with other regulations will place additional constraints on the manner that passengers might contact the devices or stowage compartments during extreme conditions such as crash landings, sudden loss of altitude, etc.

A soft stowage compartment is not likely to provide adequate protection for the device and a hard stowage container could hurt or discomfort the passengers if stowage is within the passenger's normally occupied space envelope. All of these considerations suggest that the devices must be "out of the way" of the passengers when stowed. The requirement that the location must be obvious and readily accessible when seated or standing, and the requirement that "in the case of self-help installations should not require more than a single action and no undue dexterity or force to gain access to the PPBE, suggest that the device must be either automatically presented from a secure stowage location, or integrated in a secure manner into surfaces within the reach envelope.

c) Intentional damage or vandalism

Although not specifically mentioned in the SOW as a requirement, the stowage concepts should also be such as to minimize and discourage intentional damage to the PPBE's. Many of the same considerations apply to vandalism as to pilferage, but minor damage may be hard to detect. To the extent feasible, the stowage should be "tamper-proof" to prevent:

- breaking the hermetic seal,
- denying access (eg. jamming the access panel, cutting the access handle for a self-help system, etc), or
- degrading the performance of one or more units.

d) Removing the device from stowage at an improper time

The self-help option creates another possible problem in terms of passenger behaviour. If passengers control access to the PPBE, they can access the device at an improper time. There would be a great potential for unauthorized use. Children would play with the access mechanism. Anxious passengers might panic and activate the device when they should not. Some may sit there with a hand on the access mechanism on every take-off and landing, ready to use it with the slightest provocation. A single passenger activating the device inappropriately might influence other passengers to activate their own or to show other panic responses.

There would also be potential for improper use in an actual emergency. Some passengers might open and activate the device too soon (eg. during an in-flight emergency that is not smoke related, causing their air supply to be used up before the emergency landing). This would again lead to a chain-reaction of panic among other passengers.

5.3.2 Considerations Regarding Presentation

5.3.2.1 Crew Requirements

Crew requirements regarding device presentation include the following:

a) Pre-flight instructions

The first behaviour relating to PPBE presentation is the cabin crew providing pre-flight instructions to the passengers. These instructions presently cover the emergency oxygen supply and other emergency features. New instructions will be required whether the PPBE is a combined smoke/hypoxia protection system or a fully independent smoke system. There are several features that the instructions should have including:

- attracting the attention of the passengers, without frightening them unduly,
- clearly indicating the PPBE stowage location and manner in which presentation will occur,
- clearly demonstrating the proper donning technique,
- indicating the priority for getting your own device donned and then helping others, and concepts for self-help,

- informing the passengers how to know when the devices should be accessed.

In addition to providing pre-flight instructions, passengers should be provided with printed information on the safety information card.

b) Activating automatic systems

Any automatic presentation system should be such that the cabin crew can easily activate presentation from any of their stations.

c) Signalling passengers to use self-help systems

Given a self-help concept, annunciation to the passengers to access devices should be provided.

d) Monitoring presentation

The cabin crew should have some way of monitoring the presentation of the devices to ensure that every passenger has one available. In conditions of emergency evacuation and/or thick smoke this may be very difficult, particularly if an overhead stowage/presentation scheme is not used.

e) Assisting in presentation if problems occur

The presentation method should have a low failure rate, but should also be easy to manually override when failure does occur.

5.3.2.2 Passenger Use

The human factors and behavioural issues regarding presentation of the PPBE's include:

a) Attention to information regarding location and use

For rapid performance of the behaviours necessary to access the PPBE the passengers must understand and easily remember the location of the device. This almost rules out any method whereby the passenger stows their own device.

b) Recognition of conditions when PPBE should be used

For automatic presentation systems, the presentation of the PPBE should indicate that the device should be accessed at any time that it is presented. For self-help methods of presentation, access can be controlled by the passenger, but special efforts will be required to ensure:

- that no one activates their PPBE at an improper time,
- that all passengers quickly become aware of any emergency requiring the use of the PPBE, and
- that the passenger perform the correct actions to access the unit.

c) Access to the device and preparing to don

Access to the device is a major factor in performance. The device should be accessed and donned within 10 seconds, with much of this time required for donning.

Ergonomics and human factors play an important role with regard to many factors that relate to stowage and presentation such as:

i) The ability to reach the device from a belted position, when standing in the seat row, or when standing in the aisle area.

This makes some stowage/presentation schemes, such as armrest self-help, much less desirable than others.

ii) Single-action, easy access

The device design and stowage/presentation scheme must be integrated and tested to ensure that typical, naive passengers can access the unit easily in a single action. Armrest and meal-tray locations may not always be easy.

iii) Requirements for children, infants, handicapped, or other special populations

Children pose some special problems in stowage/presentation design. The standing reach of an average seven year old child is about equal to the seated reach of an average adult woman. The seated reach of a child will depend on their location on the seat cushion. If they are belted securely in the rear of the seat cushion, they may not be able to reach the seat in front of them.

As is the case with the present hypoxia equipment, adults nearby will be expected to assist children in accessing and donning the PPBE unit. However, the conditions in which the PPBE unit may be required will probably be much more difficult and stressful than a decompression situation. Children assisted by an adult may not be able to meet the 10 second donning criterion.

The requirement for additional devices for infants who are carried on the lap of an adult leads to other considerations. It may be necessary to seat parents with infants in specific sections of the aircraft where additional units are available. Depending on the design of the unit, a smaller size may be required for infants and small children.

Handicapped, medically ill or senior passengers may have a variety of limitations that will affect their ability to access and use a PPBE unit. Passengers with some mobility impairments will have a significantly smaller reach envelope than the "design passenger" modelled after military specifications. Other passengers may have visual, hearing, or touch impairments that will pose problems for certain stowage/presentation schemes.

For most of the "special" population, the overhead or seat-back automatic presentation schemes are the most attractive. These schemes present the device closest to the user and make the least demands on physical ability, perception, memory, and understanding.

The reach envelopes in Section 4 were based on single-hand reach, whereas physically disabled people may require both hands. This would reduce the reach envelope and may possibly result in some self-help schemes (eg. underseat) to be unfeasible for this special population.

iv) Minimizing any possibility for conflict or interference between passengers under stress conditions

Certain stowage/presentation schemes are more likely to lead to competition for devices or interference between passengers. Schemes that do not clearly indicate which unit is intended for which passenger are deficient in this regard. Presentation from armrests or sidewalls can lead to ambiguities or difficulties when more than one passenger reaches for the device at the same time. Both, test situations and real evacuations, indicate that people will show extreme behaviours in a survival situation. They will attack, climb over, push aside, or trample other passengers who are in the way. The stowage/presentation schemes which clearly indicate which PPBE unit is yours, and make it easy for each passenger to access their unit without interference from other frightened and frantic passengers, will facilitate the smoothest evacuation.

v) Minimizing the time required to know how to don the device

General consideration, such as reach envelope or clear input regarding the location of the unit and the correct time to use it, can provide some guidance on stowage and presentation of PPBE units. But more information about the units, their packaging, and details of their operation will need to be integrated with in order to minimize access time and maximize the reliability of passenger responses.

The general human factor issues applicable to the stowage/presentation schemes are summarized in Tables 5.4 through 5.10.

TABLE 5.4 - HUMAN FACTOR ISSUES FOR STOWAGE/PRESENTATION SCHEMES - OVERHEAD AUTOMATIC

SCENARIO

During an emergency situation, units would automatically drop down from overhead stowage into passenger reach envelope.

PROS

1. Passengers all have a clear indication of an emergency condition.
2. The stowage location would interfere minimally with passenger movement, comfort, and activities. Routine inspection and monitoring of emergency deployment would be facilitated in this location. This location would also minimize damage, tampering and pilferage.
3. Safety instructions could be integrated with those for hypoxia systems.
4. Inspection of the devices could become an easy part of the pre-flight routine, or could be done by ground crews before each flight.
5. The requirement for additional devices, accessible from the aisles, would be most compatible with this scheme.
6. Would probably alleviate the reach envelope problem for passengers out of the 5 to 95 percentile.

CONS

1. Major aircraft modifications would be required.
2. Units that were deployed but not used may provide some interference with evacuation.

CONCLUSION

Although the alterations to the airplane pose problems, the potential for human error is greatly decreased by presenting the PPBE to passengers automatically.

TABLE 5.5 - HUMAN FACTOR ISSUES FOR STOWAGE/PRESENTATION SCHEMES - OVERHEAD SELF-HELP

SCENARIO

Upon noticing an emergency situation, or upon perceiving an emergency signal initiated by the crew the passenger would access the PPBE from an overhead stowage location.

PROS

1. Some passengers near a localized fire might access and don the device more quickly with a self-help scheme.
2. A simple stowage/deployment interface would be required in order to minimize malfunction.
3. Inspection of the devices could become an easy part of the pre-flight routine, or could be done by ground crews before each flight.
4. The location would minimize damage, tampering and pilferage.

CONS

1. The stowage location would be out of easy reach for small passengers.
2. Instructions would be more difficult to provide than for automatic presentation schemes, and reliability of passenger response to the emergency and access to the unit would be decreased.
3. There would be some potential for unauthorized use. Some passengers might damage the units, while anxious passengers may panic and activate the device when it is not required. A single passenger activating the device inappropriately may influence other passengers to activate their own or to show other panic responses.
4. There would also be potential for improper use in an actual emergency. Some passengers may open and activate the device prematurely (eg. during and in-flight emergency that did not affect the cabin interior, causing their air supply to be used up before the emergency landing). This would lead to panic among other passengers.

CONCLUSION

Although passenger control could help some passengers in some situations, the potential for human error is increased, and the anthropometric requirements for access by most passengers would be difficult to meet.

TABLE 5.6 - HUMAN FACTOR ISSUES FOR STOWAGE/PRESENTATION SCHEMES - SEAT-BACK OR HEADREST AUTOMATIC

SCENARIO

During an emergency situation, units would be automatically presented from the seat in front into passenger reach envelope.

PROS

1. All passengers have a clear indication of an emergency condition.
2. Most passengers could reach their device easily from a seated, belted position.

CONS

1. Due to discontinuities, the same stowage location could not be used for all seats. Stowed devices would be more difficult to visually inspect than overhead stowage.
2. Units that were deployed but not used might provide some interference with evacuation.

CONCLUSION

Most passengers could easily notice and reach their PPBE with this stowage/presentation scheme. However, the device would be more difficult to inspect than with the overhead automatic scheme.

TABLE 5.7 - HUMAN FACTOR ISSUES FOR STOWAGE/PRESENTATION SCHEMES - SEAT-BACK OR HEADREST SELF-HELP

SCENARIO

Upon noticing an emergency situation, or upon perceiving an emergency signal initiated by the crew, the passenger would access the PPBE from a stowage location in the seat back directly in front of their own seat.

PROS

1. Some passengers near a localized fire might access and don the device more quickly with a self-help scheme.
2. A simple stowage/deployment interface could be used that would be unlikely to malfunction.
3. Most passengers could reach their device easily from a seated and belted position.

CONS

1. Due to discontinuities, the same stowage location could not be used for all seats. Stowed devices would be more difficult to inspect by a simple visual check.
2. Instructions would be more difficult to provide than for automatic presentation schemes, and reliability of passenger response to the emergency and access to the unit would be decreased.
3. There would be some potential for unauthorized use. Some passengers may damage the units or try to pilfer them. Anxious passengers might panic and activate the device when they should not. A single passenger activating the device inappropriately may influence other passengers to activate their own.
4. There would also be potential for improper use in an actual emergency. Some passengers may open and activate the device prematurely. This would lead to panic among other passengers.

CONCLUSION

Although passenger control could help some passengers in some situations, the potential for human error is increased, and the devices would be more difficult to protect and inspect than automatic presentation.

TABLE 5.8 - HUMAN FACTOR ISSUES FOR STOWAGE/PRESENTATION SCHEMES - UNDER-SEAT OR SEAT POUCH SELF-HELP

SCENARIO

Upon noticing an emergency situation, or upon perceiving an emergency signal initiated by the crew, the passenger would access the PPBE from a stowage location under the seat or in the seat pouch directly in front of their own seat.

PROS

1. Some passengers near a localized fire might access and don the device more quickly with a self-help scheme.
2. A simple stowage/deployment interface would be required in order to minimize malfunction.

CONS

1. Due to discontinuities the same stowage location could not be used for all seats. Stowed devices would be very difficult to visually inspect and may be susceptable to damage.
2. Instructions would be more difficult to provide than for automatic presentation schemes, and reliability of passenger response to the emergency and access to the unit would be decreased.
3. There would be some potential for unauthorized use. Some passengers may damage the units or try to pilfer them. Anxious passengers may panic and activate the device when they should not. A single passenger activating the device inappropriately may influence other passengers to activate their own or to show other panic responses.
4. There would also be potential for improper use in an actual emergency. Some passengers may open and activate the device prematurely thus leading to panic.
5. Many passengers may have difficulty accessing the unit because of their own physical constraints, or because of meal trays, carry-on bags, etc.

CONCLUSION

Although passenger control could help some passengers in some situations, the potential for human error is increased, and the devices would be more difficult to access, protect and inspect.

TABLE 5.9 - HUMAN FACTOR ISSUES FOR STOWAGE/PRESENTATION SCHEMES - SEAT ARMREST OR MEAL-TRAY SELF-HELP

SCENARIO

Upon noticing an emergency situation, or upon perceiving an emergency signal initiated by the crew, the passenger would access the PPBE from a stowage location in the seat armrest or the meal-tray.

PROS

1. Some passengers near a localized fire might access and don the device more quickly with a self-help scheme.
2. Depending on the stowage of the PPBE, many passengers would be aware of the PPBE presence since the meal-tray is used frequently.

CONS

1. Due to discontinuities the same stowage location could not be used for all seats. Stowed devices, particularily in the case of armrest, would be more difficult to inspect by a simple visual check.
2. Instructions would be more difficult to provide than for automatic presentation schemes, and reliability of passenger response to the emergency and access to the unit would be decreased.
3. There would be some potential for unauthorized use. Some passengers may damage the units or try to pilfer them. Anxious passengers may panic and activate the device when they should not. A single passenger activating the device inappropriately may influence other passengers to activate their own.
4. There would also be potential for improper use in an actual emergency. Some passengers may open and activate the device prematurely. This would lead to panic among other passengers.
5. The PPBE units are very susceptable to damage since armrests and meal-trays are often used.
6. Confusion to the passengers is likely in the case of armrest, since he/she would not know which armrest (right or left) to access.

CONCLUSION

Although passenger control could help some passengers in some situations, the potential for human error is increased, and the devices would be more difficult to protect and inspect than automatic presentation.

TABLE 5.10 - HUMAN FACTOR ISSUES FOR STOWAGE/PRESENTATION SCHEMES - PASSENGER CARRY-ON

SCENARIO
Upon boarding (either in the boarding lounge, upon entry to the plane, or when all passengers are seated) the flight attendants distrubute the PPBE to each passenger. The passenger then has the responsiblity for proper stowage and retrieval of the device.
PROS
1. No aircraft modifications would be required. The same procedures could be used for all aircraft and airlines. 2. No stowage/deployment interface would be required which may malfunction. The responsibility for deployment would be shifted more to the passenger. (This might represent some legal or technical advantage for the airline but would probably decrement overall deployment.) 3. Safety instructions would probably have a greater impact on the passengers, since being given the device would require active attention on their part. 4. Checking the devices could become an easy part of the distribution routine, or could be done by ground crews before each flight.
CONS
1. A very great amount of time and effort would be required to check, distribute, and collect the devices for each flight. It would be a particular problem on deplanning to ensure that the devices are returned undamaged. 2. Because there would be some novice flyers on every flight, the attendant would have to advise each passenger why they were given the device. A brief explanation may be sufficient for frequent flyers, however novice flyers may not be satisfied. If it was all explained in the boarding lounge, this would create apprehension before the passenger makes the behavioural committment of boarding the plane. (The more anxious passengers may then decide to take the train.)

TABLE 5.10 - Continued

3. There would be a great potential for unauthorized use. Children would play with the devices. Anyone might break the seal by improper handling. Vandals, disgruntled, or intoxicated passengers may damage the units. Anxious passengers may panic and activate the device when they should not. Some would probably sit there clutching it tightly on every take-off and landing, ready to use it with the slightest provocaton. A single passenger activating the device inappropriatley may influence other passengers to activate their own or to show other panic responses.

4. There would also be potential for improper use in an actual emergency. Some passengers may open and activate the device prematurily (e.g. during an in-flight emergency that did not affect the cabin interior, causing their air supply to be used up before the emergency landing). This may lead to panic among other passengers. Other passengers would probably misplace the device, forgetting where they put it, or buried it under coats or other belongings.

CONCLUSION

Although the idea of minimizing alterations to the airplane has some appeal, the potential for human error is increased to unacceptable levels by allowing the passengers too much control over their PPBE.

6. COST ANALYSIS

This section considers implementation and recurring costs for each of the schemes identified in Section 4.3. The costing is based on the requirements identified throughout this report, such as the physical constraints of Section 5.2. Although subjective, the cost figures can be used with reasonable confidence for comparing the PPBE schemes. Capital costs were obtained from equipment manufacturers, air carriers or parts suppliers, while labor rates were obtained from a firm specializing in aircraft modifications.

6.1 Implementation Costing Methodology

The cost analysis considers that PPBE system installations are performed while the aircraft undergoes scheduled maintenance. Overhead modifications are performed when an aircraft is receiving interior retrofits or airframe checks requiring the removal of interior equipment, while seat modifications are performed when seats are removed for reupholstering.

The PPBE installation costs are presented on a 'per seat' basis. This allows application of the results to any size aircraft, as well as considerably simplifying the analysis (eg. for seven aircraft types and ten stowage/presentation schemes, 70 detailed cost estimates would be required). The cost analysis was prepared for a medium size transport category aircraft in air carrier service such as the B-727. While unit costs for larger aircraft may be somewhat lower, and those for small aircraft somewhat higher, the cost variation is not believed to be significant.

6.1.1 Detailed Installation Costs

Implementation costs are summarized in Table 6.1 for both self-contained PPBE units, and those which are partially dependent on a remote oxygen supply (see Section 2.7).

The detailed installation cost analysis is presented in Appendix D and includes cost parameters such as the following:

- Labor required for the annunciation system installation and associated modifications required to the aircraft.
- Labor required to remove and restore existing systems and subsystems displaced by the PPBE.
- Labor required to install PPBE and reinstall systems and miscellaneous components.
- Labor required to modify seats or seat parts to allow for installation of the PPBE.
- Labor required to reinstall aircraft components such as PSU panels, baggage bins and false ceilings.
- Labor required to relocate existing components and systems.
- Cost of PPBE unit + 10 per cent to allow for the additional units required on aircraft (precise PPBE cost is unknown).

TABLE 6.1 - IMPLEMENTATION COSTS PER SEATING POSITION FOR SELF-CONTAINED AND DEPENDENT PPBE SYSTEMS

Stowage/Presentation Scheme	Self-Contained Implementation Cost (Can. $)	Dependent Implementation Cost (Can. $)
Overhead Automatic	2222	2333
Overhead Self-Help	1713	1805
Seat-back Automatic	1991	2101
Seat-back Self-Help (Flush with seat-back)	1544	1674
Seat-back Self-Help (External pouch or pocket)	1251	1366
Underseat Self-Help	982	1092
Carry-on Self-Help	568	N.A.
Seat Armrest Self-Help	1796	2031
Seat Meal-tray Self-Help	1259	1389
Smoke/Hypoxia overhead automatic scheme	N.A.	2403

- Miscellaneous capital equipment cost not specifically identified including additional hardware, controls, sensors, circuitry, wiring, fabrics, etc.

- Engineering studies, supplier surveys, feasibility studies, preliminary design studies and liaison.

- Engineering support such as engineering drawings, analysis, project planning, compliance & certification, impact studies, manufacturing support and purchasing.

- Other engineering support such as purchasing, shipping, receiving, handling, etc.

Non-recurring costs associated with testing and certification of PPBE systems have not been estimated, although it is recognized that they may be substantial. This will be of particular importance if successful evacuation demonstrations will be required for each system, air carrier, and aircraft type. In addition, there will be both initial and recurrent cabin crew training expenses. It is not believed, however, that these will differ substantially among various PPBE schemes.

The following cost estimates, in Canadian dollars, are used for the analysis:

- Cost of PPBE Unit(1)	$300.
- Engineering labor rate/hour	$58.
- Other labor rates/hour	$48.

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(1) Ten percent has been added in the analysis for the extra required units, to yield a cost per seat of $330.

The material costs for each stowage/presentation scheme are detailed in Appendix D.

6.2 Recurring Costs

Estimates of recurring costs, on a per seat per year basis, are summarized in Table 6.2, and are based on cost and weight parameters as follows:

Unit weight - 0.50 kg (1.1 lbs)
Unit cost - C $300.
Support weight(2) (automatic) - 0.32 kg (0.7 lbs)
Stowage enclosure weight (self-help) - 0.14 kg (0.3 lbs)
Support Weight (carry-on) - 0.0 kg (0.0 lbs)

The key recurring cost elements have been estimated according to the following rationales.

6.2.1 Pilferage

Loss of existing equipment (such as life vests) is a major problem in most carriers, but the extent of the loss can vary widely. No readily acceptable estimates are available. For the purpose of this study, it has been assumed that the passenger carry-on scheme will have a loss rate of 20%/year ($66 per seat), self-help schemes will have a 10% attrition rate/year ($33 per seat), while automatic deployment should not be subject to pilferage.

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(2) Stowage enclosure plus lines, manifolds, electrical wires, etc.

TABLE 6.2 - RECURRING COSTS (per seat per year)

Stowage/Presentation Scheme	Unit Costs due to: (in Canadian dollars)					
	Pilferage	Weight	Carrying Costs	Inspection/ Maintenance	Servicing	Total
Overhead Automatic	-	40	222	32	96	390
Overhead Self-Help	33	31	171	17	96	348
Seat-back Auto-Presentation	-	40	199	32	96	367
Seat-back Self-Help (Flush with seat-back)	33	31	154	17	96	331
Seat-back Self-Help (External pouch or pocket)	33	31	125	17	96	302
Underseat Self-Help	33	31	98	17	96	275
Carry-on Self-Help	66	24	57	-	96	243
Seat Armrest Self-Help	33	31	180	17	96	357
Seat Meal-tray Self-Help	33	31	126	17	96	303
Smoke/Hypoxia overhead automatic scheme	-	40	240	32	96	408

6.2.2 Weight Penalty

Aircraft fuel consumption data, taken from recent U.S. statistics, are in the range of .0418 liters per kilogram (.005 U.S. gallons per pound) of aircraft weight per hour for wide bodies, and up to about .0836 (.01 U.S. gallons per pound) for narrow bodied equipment. Based on 3,500 hours utilization for wide bodies and 2,500 hours for narrow bodies annual fuel costs of 146 liters per kilogram per year (17.5 gallons per pound per year) for wide bodies, and 209 litres (25 gallons) for smaller equipment can be estimated. Using 167 litres (20 gallons) on average, at C$0.26 per litre (C$1 per gallon), yields a fuel cost of $44 per kilogram per year ($20 per pound per year).

Given per seat unit weights of 0.82 kilograms (1.8 lbs) for automatic systems, 0.64 kilograms (1.4 lbs) for self-help, and 0.5 kilograms (1.1 lbs) for carry-on systems, yield annual per seat fuel costs of $40 for automatic systems, $31 for self-help ones, and $24 for carry-on systems.

6.2.3 Carrying Costs

Carrying costs have been arbitrarily assumed to total 10% per year of the lower of the two costs presented in Table 6.1. This is considered conservative as, in many instances, the opportunity cost of capital may be much higher.

6.2.4 Inspection and Maintenance Costs

Inspection and maintenance costs should be similar to those experienced with oxygen systems, and should average one half hour per unit per year for automatic systems, and one quarter hour per unit per year for self-help systems. No separate maintenance is required for carry-on systems. At a C $58 labor rate, automatic systems will cost $32 per year, self-help $17, and carry-on zero, including an allowance for spare equipment.

6.2.5 Servicing Costs

Servicing costs are estimated at 15 seconds per unit per day for all systems. This is about 1½ hours per unit per year, or, at a C$ $58 labor rate, about $96 per unit per year, including spares.

6.2.6 Revenue Loss

Revenue loss is due to inability to board additional cargo and/or passengers at Maximum Gross Take Off Weight (MGTOW). As most airlines operate with average load factors in the 60-70% range, and do not reach MGTOW unless substantial cargo loads are also carried, the number of times when revenue is lost is difficult to quantify.

6.2.7 Summary

As Table 6.2 shows, the range of recurring costs extends from a low of about $250 per unit per year, to a high of about $400 (8-13 cents per hour per seat, based on 3,000 hours utilization).

7. SYSTEM EVALUATION

The objective of this section is to evaluate the numerous schemes defined in Section 4, based on the constraints in Section 5 and the costs in Section 6, by using decision analysis techniques and detailed sensitivity tests. Two independent sets of Binary Decision Analyses were conducted, eight tests to determine the sensitivity of the ranking for changes to the criteria, as well as a cost sensitivity.

7.1 Binary Decision Analyses

In order to assist in the identification and definition stowage and presentation concepts for PPBE, two independent sets of Binary Decision Analyses were conducted under the following scenarios:

- Aircraft with large cross-sectional diameters.
- Aircraft with small cross-sectional diameters.

The difference between the two scenarios accounts for the passenger reach envelopes (ie. the overhead self-help scheme is not feasible for aircraft with large diameters). A discussion for passengers seated at discontinuities such as in front of bulkheads, facing an emergency exit and flight attendant seating is found in Section 5.

7.1.1 Introduction and Theoretical Background

In order to rank all the stowage/presentation concepts in order of preference, it is necessary to evaluate each concept's ability to satisfy a series of diverse selection criteria, or a set of "decision variables". The evaluation technique used to establish the ranking is a type of decision analysis developed by Westinghouse in the United States. The Consultants have modified and adapted the technique for aviation problem solving. It is essentially a systematic, formalized procedure for solving complex decision problems.

The series of steps to be followed in the binary decision analysis technique to arrive at a ranking of the stowage/presentation concepts for a given scenario are given in Appendix E. Furthermore, a sample computation using three criteria and two alternatives is also given in Appendix E.

7.1.2 Criteria Weighting

The criteria used include both quantitative and qualitative factors which must be considered in defining the stowage/presentation schemes for PPBE. A long list of criteria was reduced to the following five independent factors in order to assure that the criteria are mutually exclusive and collectively exhaustive. These criteria were derived from Section 5 and 6 of the report and are discussed below.

a) Recognition and Access Time

The passenger must recognize that an emergency situation requiring a PPBE device exists. The stowage/presentation characteristics must be such that PPBE will be put into effective use by the passenger in a minimum time period. Since "donning" is device specific, mask donning time is not considered, however the time period required for gaining access and retrieving the device is considered for this criteria.

b) **Usability (Damage, Tampering, Pilferage) and Inspectability**

The type, design and location of the stowage scheme should be such as to minimize the possibility of damage (ie. physical damage induced from passenger movement, tampering, pilferage and misplacement of the device). This criteria also considers deployment reliability with respect to the stowage location.

In addition, the stowage scheme must be such as to provide a clear indication to the cabin attendants if the PPBE has been tampered with. This indication should be such as to attract the cabin attendant's attention without the necessity of a unit inspection.

c) **Real time emergency crew tasking**

During emergency scenarios, crew input in recognizing needs and subsequent aid should be minimized. From the flight attendant stations, the following should be confirmed by the flight attendants:

- PPBE is deployed.
- PPBE is donned.
- Passengers are under control.

d) **Installation Costs**

The installation costs include those outlined in Section 6.1.1 and Table 6.1.

e) Recurring Costs

The recurring costs (see Table 6.2) include the costs required to assure that the system and its units are functioning properly. These costs include:

- maintenance and system inspection costs.
- pilferage/replacement costs.
- additional aircraft operating costs due to added weight.
- Since the carrying costs are a function of the capital costs, these are not included for this criteria.

It should be noted that the analysis assumes that the PPBE system 'will deploy' from the stowage enclosure during an emergency condition. Airworthiness regulations demand that automatic aircraft systems, including the present hypoxia systems, have a high reliability against system failure. Furthermore, for these automatic PPBE installations, draft specifications state that back-up manual access (as for hypoxia systems) should be considered for automatic installations.

Having identified the five major decision criteria, relative weights to each criterion are attached as illustrated in Table 7.1 (See Appendix E, Step 2 for theory on derivation of Table 7.1). It is to be noted that the weights were determined, by consensus, with the assistance of all the team members. It can be seen from Table 7.1 that recognition and access time ranked highest (weight of 33.3 per cent), followed by usability and installation costs (each with a

TABLE 7.1

RESULTS OF CRITERIA WEIGHTING EXERCISE

CRITERIA	RAW SCORE	TOTAL	TRANSFORMED SCORE	CRITERIA WEIGHT
1. Rcgn/Access Time	1 1 1 1	4.0	5.0	33.3
2. Usability	0 1 = 1	2.5	3.5	23.3
3. Crew Tasking	0 0 0 0	0.0	1.0	6.7
4. Installation Costs	0 = 1 1	2.5	3.5	23.3
5. Recurring Costs	0 0 1 0	1.0	2.0	13.3
TOTAL		10.0	15.0	100.0

weight of 23.3 per cent). Recurring costs and emergency crew tasking were of less importance with a weighting of 13.3 and 6.7 per cent, respectively.

7.1.3 Stowage/Presentation Concepts

The following PPBE stowage/presentation schemes as depicted in Section 4.3 are used for this analysis:

- Overhead Automatic Presentation
- Overhead Self-Help
- Seat-back Automatic Presentation
- Seat-back Self-Help (Flush with seat-back)
- Seat-back Self-Help (Pouch or Seat-Pocket)
- Underseat Self-Help
- Carry-on Self-Help
- Seat Armrest Self-Help
- Seat Meal-tray Self-Help

7.1.4 Scenarios Considered

Two independent sets of analysis were conducted (See Section 7.1). As described in Appendix E, Step 3, each scheme was assessed on the basis of the ability to satisfy the criterion being considered. Weights were systematically assigned to each scheme and the results are presented in Tables 7.2 and 7.3 for large and small aircraft cross-sections, respectively.

Application of the criteria weights (Table 7.1) to the evaluation scores (Tables 7.2 and 7.3), results in final weighted scores for each scheme. This was derived using the

TABLE 7.2 - RESULTS OF CRITERIA 1 THROUGH 5 - LARGE AIRCRAFT CROSS-SECTIONS

Stowage/Presentation Scheme	Criteria (per cent)				
	1	2	3	4	5
Overhead Auto-Presentation	22.2	22.2	22.2	2.8	20.5
Seatback Auto-Presentation	19.4	19.4	19.4	5.6	20.8
Seatback Self-Help (Flush with seat back)	13.9	16.7	16.7	11.1	11.1
Seatback Self-Help (External pouch or pocket)	16.7	13.9	13.9	16.7	11.1
Underseat Self-Help	11.1	11.1	11.1	19.4	11.1
Carry on Self-Help	2.8	2.9	2.8	22.2	2.8
Seat Armrest Self-Help	6.9	6.9	6.9	8.3	11.1
Seat Mealtray Self-Help	6.9	6.9	6.9	13.9	11.1
TOTAL	100	100	100	100	100

CRITERIA INDEX:
1. Rcgn/Access Time
2. Usability
3. Crew Tasking
4. Installation Costs
5. Recurring Costs

TABLE 7.3 - RESULTS OF CRITERIA 1 THROUGH 5 - SMALL AIRCRAFT CROSS-SECTIONS

Stowage/Presentation Scheme	Criteria (per cent)				
	1	2	3	4	5
Overhead Auto-Presentation	20.0	20.0	20.0	2.2	18.9
Overhead Self-Help	8.9	15.6	15.6	8.9	10.0
Seatback Auto-Presentation	17.8	17.8	17.8	4.4	18.9
Seatback Self-Help (Flush with seat back)	13.3	13.3	13.3	11.1	10.0
Seatback Self-Help (External pouch or pocket)	15.6	11.1	11.1	15.6	10.0
Underseat Self-Help	11.1	8.9	8.9	17.8	10.0
Carry on Self-Help	2.2	2.2	2.2	20.0	2.2
Seat Armrest Self-Help	5.6	5.6	5.6	6.7	10.0
Seat Mealtray Self-Help	5.6	5.6	5.6	13.3	10.0
TOTAL	100	100	100	100	100

CRITERIA INDEX:
1. Rcgn/Access Time
2. Usability
3. Crew Tasking
4. Installation Costs
5. Recurring Costs

theory described in Appendix E, Step 4. The results are presented in Tables 7.4 and 7.5 for large and small aircraft, respectively.

It can be seen that the most desirable schemes are the automatic presentation schemes, followed very closely by the three seat based self-help schemes.

TABLE 7.4
LARGE AIRCRAFT CROSS-SECTIONS
FINAL SCORES AND RANKING

Stowage Location	Score Per Criteria (per cent)					
	1	2	3	4	5	Total Score
1. Overhead Auto-Presentation	7	5	1	1	3	17.5
2. Seatback Auto-Presentation	6	5	1	1	3	16.4
3. Seat Pocket Self-Help	6	3	1	4	1	15.1
4. Seatback Self-Help	5	4	1	3	1	13.7
5. Underseat Self-Help	4	3	1	5	1	13.1
6. Mealtray Self-Help	2	2	0	3	1	9.1
7. Armrest Self-Help	2	2	0	2	1	7.8
8. Carry on Self-Help	1	1	0	5	0	7.3
TOTAL						100.0

CRITERIA INDEX:
1. Rcgn/Access Time
2. Usability
3. Crew Tasking
4. Installation Costs
5. Recurring Costs

SOURCE: Aviation Planning Services Ltd.

TABLE 7.5
SMALL AIRCRAFT CROSS-SECTIONS
FINAL SCORES AND RANKING

Stowage Location	Score Per Criteria (per cent)					Total Score
	1	2	3	4	5	
1. Overhead Auto-Presentation	7	5	1	1	3	15.7
2. Seatback Auto-Presentation	6	4	1	1	3	14.8
3. Seat Pocket Self-Help	5	3	1	4	1	13.5
4. Seatback Self-Help	4	3	1	3	1	12.4
5. Underseat Self-Help	4	2	1	4	1	11.9
6. Overhead Bin Self-Help	3	4	1	2	1	11.0
7. Mealtray Self-Help	2	1	0	3	1	8.0
8. Armrest Self-Help	2	1	0	2	1	6.4
9. Carry on Self-Help	1	1	0	5	0	6.4
TOTAL						100.0

CRITERIA INDEX:
1. Rcgn/Access Time
2. Usability
3. Crew Tasking
4. Installation Costs
5. Recurring Costs

7.2 Sensitivity Analysis

A sensitivity analysis on the Binary was conducted in order to test the results in Tables 7.4 and 7.5. Since the criteria weighting will vary according to what one individual may consider important, a number of different tests were developed.

For example, the analysis in Tables 7.4 and 7.5 had usability and installation costs weighted equally. If one performs a sensitivity test and ranks installation costs above usability (an airline operator might prefer this order of importance), the results under column 1 of Table 7.6 would be obtained for large aircraft cross-sections. It can be seen that the only change in ranking involves the carry-on and armrest schemes.

Similarly, if usability is weighted higher than installation cost (one who considers safety more important than cost might prefer this order of importance), then the results would not change from the original ranking. These results are depicted in column 2 of Table 7.6.

A third test was developed with installation costs weighted above all other criteria, while a fourth test with both installation and recurring costs weighted above all other criteria. The results of the above sensitivity tests are also presented in Table 7.6, in columns 3 and 4.

It can be seen that the ranking of the schemes does not change significantly. The following important observations can be made:

TABLE 7.6 - SENSITIVITY ANALYSIS - LARGE AIRCRAFT CROSS-SECTIONS

	Original Ranking		Sensitivity Test #							
			1		2		3		4	
Criteria Weights	%	rank	%	rank	%	rank	%	rank	%	rank
1. Rcgn/Access Time	33.3	1	33.3	1	33.3	1	26.7	2	20.0	3
2. Usability	23.3	2	20.0	3	26.7	2	20.0	3	13.3	4
3. Crew Tasking	6.7	5	6.7	5	6.7	5	6.7	5	6.7	5
4. Installation Cost	23.3	2	26.7	2	20.0	3	33.3	1	33.3	1
5. Recurring Cost	13.3	4	13.3	4	13.3	4	13.3	4	26.7	2
TOTAL	100		100		100		100		100	
Final Scores and Ranking										
1. Overhead Bin - Auto	17.5	1	16.9	1	18.1	1	15.6	1	15.4	1
2. Seat - Auto	16.4	2	15.9	2	16.9	2	15.0	3	15.2	2
3. Seat Pocket - Self	15.1	3	15.2	3	15.0	3	15.2	2	14.6	3
4. Seat - Self	13.7	4	13.5	4	13.9	4	13.3	5	12.8	5
5. Underseat - Self	13.1	5	13.3	5	12.8	5	13.9	4	13.9	4
6. Mealtray - Self	9.1	6	9.4	6	8.9	6	9.8	6	10.4	6
7. Armrest - Self	7.8	7	7.9	8	7.8	7	8.0	8	8.5	8
8. Carry on - Self	7.3	8	8.0	7	6.7	8	9.3	7	9.3	7
TOTAL	100		100		100		100		100	
MEAN SCORE	12.5		12.5		12.5		12.5		12.5	
STANDARD DEVIATION	3.7		3.4		4.0		2.8		2.6	

- Overhead bin Automatic always ranks highest.
- Seat-back Automatic and seat pocket Self-help always rank second or third.
- The seat and underseat self-help schemes rank fourth and fifth for all test cases.
- Meal-tray self-help ranks sixth in all cases.
- Armrest and carry-on rank seventh or eigth for all cases.

To summarize, it can be concluded that reasonable variations in the weightings will not significantly change the final scores and rankings. As stated in the preceding section, the automatic schemes rank highest, followed closely by the seat based schemes. The meal-tray, armrest and carry-on schemes have the worst scores.

One other noteworthy point is that, as costs become more important, the standard deviation from the mean score becomes smaller and smaller. This can be seen in Table 7.6 for sensitivity tests one, three and four.

A sensitivity analysis was also prepared for small aircraft cross sections, with the results depicted in Table 7.7. The results are similar to those with large diameters. The overhead bin self-help scheme ranks sixth for all sensitivity tests.

TABLE 7.7 - SENSITIVITY ANALYSIS - SMALL AIRCRAFT CROSS-SECTIONS

	Original Ranking		Sensitivity Test #							
			1		2		3		4	
Criteria Weights	%	rank	%	rank	%	rank	%	rank	%	rank
1. Rcgn/Access Time	33.3	1	33.3	1	33.3	1	26.7	2	20.0	3
2. Usability	23.3	2	20.0	3	26.7	2	20.0	3	13.3	4
3. Crew Tasking	6.7	5	6.7	5	6.7	5	6.7	5	6.7	5
4. Installation Cost	23.3	2	26.7	2	20.0	3	33.3	1	33.3	1
5. Recurring Cost	13.3	4	13.3	4	13.3	4	13.3	4	26.7	2
TOTAL	100		100		100		100		100	
Final Scores and Ranking										
1. Overhead Bin - Auto	15.7	1	15.1	1	16.3	1	13.9	1	13.8	1
2. Seat - Auto	14.8	2	14.4	2	15.3	2	13.5	3	13.6	2
3. Seat Pocket - Self	13.5	3	13.6	3	13.3	3	13.6	2	13.2	3
4. Seat - Self	12.4	4	12.3	4	12.4	4	12.1	5	11.7	5
5. Underseat - Self	11.9	5	12.1	5	11.6	5	12.6	4	12.6	4
6. Overhead Bin - Self	11.0	6	10.8	6	11.3	6	10.8	6	10.5	6
7. Mealtray - Self	8.0	7	8.2	7	7.7	7	8.7	7	9.3	7
8. Armrest - Self	6.4	8	6.4	9	6.4	8	6.5	9	7.1	9
9. Carry on - Self	6.4	9	7.0	8	5.8	9	8.1	8	8.1	8
TOTAL	100		100		100		100		100	
MEAN SCORE	11.1		11.1		11.1		11.1		11.1	
STANDARD DEVIATION	3.3		3.0		3.5		2.6		2.3	

7.3 Sensitivity to Costs

Further analysis was also conducted to determine the relationship between system cost and system "desirability", as measured by objective factors. System cost is simply the cost of each of the schemes, while system "desirability" is measured using a weighted analysis technique.

The first step required for the determination of desirability is to enumerate a list of criteria. The criteria used for the analysis include the functional and physical constraints discussed in Sections 5.1 and 5.2, and these are listed in Table 7.8. In order to provide a more global analysis, the autocorrelation restrictions ("mutually exclusive" criteria) were relaxed, and certain other criteria were combined.

For the purposes of this analysis, weights were arbitrarily selected by the Consultants. As additional analysis allowed the evaluation of variations in the basic binary criteria, the weighting factors were allowed to vary as well. This particular sensitivity test uses weights selected by an organization with substantial aircraft maintenance experience. Despite some differences, it is noteworthy how little the final rankings were affected.

The weighting factors ranged from 0 to 10. The independent weighting factors applied to the criteria parameters represented the relative importance attached to each. A weighting of 10 therefore reflected a strong requirement to optimize that criteria, whereas a weighting factor of 3 suggested a weak requirement to optimize that criteria. The weighting factors are also listed in Table 7.8.

TABLE 7.8 - CRITERIA PARAMETERS - WEIGHTED ANALYSIS

Evaluation Criteria	Independent Weighting Factor
EC1 - Usability (Pilferage, Tampering and Damage)	8
EC2 - Emergency Recognition, Deployment and Donning Time Minimization	10
EC3 - Scenario Exclusivity	8
EC4 - Cabin Crew Tasking	7
EC5 - Post Deployment Donning Considerations	3

The second step required for the determination of scheme desirability is to enumerate the various schemes defined in Section 4.3. An additional scheme not included in Section 4.3, namely, the combined smoke/hypoxia overhead automatic presentation scheme was also considered as it may represent the most feasible long term solution. It is unlikely, however, to be a viable option if systems are to be retrofitted on existing equipment. Therefore, the cost sensitivity analysis included the same schemes in Section 7.1.3 as well as the combined smoke/hypoxia overhead automatic presentation scheme, and these are listed in Table 7.9. Once again weights ranging from 0 to 10 are arbitrarily assigned.

The weighting factors utilized for this analysis are consistent with the subjective observations made in Section 5.1 (Functional Constraints) and Section 5.2 (Physical Constraints). The quantitative results of Section 6 (Costing Analysis) were utilized in the postprocessing of the weighted analysis.

The analysis provides more detail as to how the final stowage/presentation scheme desirability rankings are established. Flexibility is afforded since one can easily alter the weighting factors, thereby deriving his/her own independent conclusions as compared to the particular subjective interpretations presented in Table 7.9.

The weighting factors are assigned with the basic assumption that the selected scheme will not be outside the allowable reach envelopes. This would obviously invalidate that scheme for the particular aircraft considered.

Table 7.9 - Dependent Weighting Factor Assignment

Scheme	Criteria				
	EC1	EC2	EC3	EC4	EC5
Overhead Automatic	10	10	5	10	8
Overhead Self-Help	8	6	5	6	8
Seat-back Automatic	8.5	9.5	5	9	6
Seat-back Self-Help (Flush/Inside)	5	7.5	5	5.5	10
Seat-back Self-Help (Pouch/Pocket)	4.5	8	5	5.3	10
Underseat Self-Help	4	6.5	5	5	6
Carry-On Self-Help	1	3	5	4	6
Seat Armrest Self-Help	3	5	3	4.5	6
Seat Meal-tray Self-Help	3	5	5	4.5	4
Smoke/Hypoxia Overhead Automatic Scheme	10	10	10	10	6

LEGEND
EC1 - Usability (Pilferage, Tampering and Damage)
EC2 - Emergency Recognition, Deploymennt and Donning Time Minimization
EC3 - Scenario Exclusivity
EC4 - Cabin Crew Tasking
EC5 - Post Deployment Donning Considerations

The total 'desirability' of a scheme with respect to the evaluation criteria is obtained by summing the product of each independent weighting factor (Table 7.8) by the corresponding weighting (Table 7.9). Results are presented in Table 7.10. Maximum possible scoring will lead to a 'scheme desirability' of 360.

Scheme 'desirability' versus expenditure is presented in Figure 7.1 and Figure 7.2 for the self-contained and non self-contained PPBE type schemes, respectively. It is noted that the 'passenger carry-on self-help' scheme is not included with the non self-contained PPBE grouping since this would not satisfy the PPBE specification criteria for single action donning.

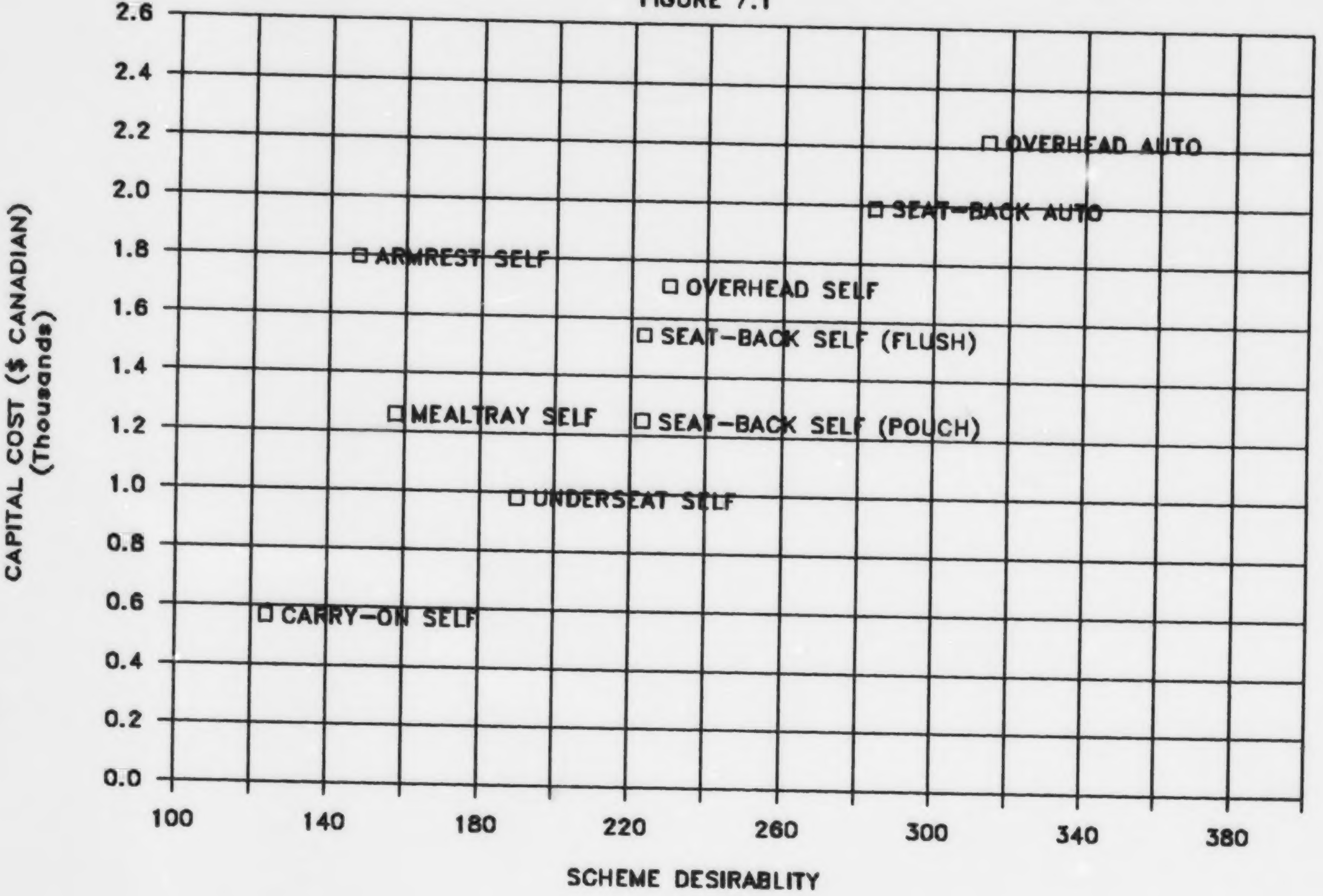
One can observe in Figures 7.1 and 7.2, that if the armrest self-help scheme was discarded, then a straight line can be fitted through the data points. Since the coefficient of correlation is 0.88 and 0.85 for the self-contained and non self-contained schemes, one can induce that a strong linear relationship exists between capital cost and desirability.

TABLE 7.10 SCHEME 'DESIRABILITY' - WEIGHTED ANALYSIS

Scheme	Desirability
Smoke/Hypoxia Overhead Automatic Scheme	348
Overhead Automatic	314
Seat-back Automatic	284
Overhead Self-Help	230
Seat-back Self-Help (Flush/Inside)	224
Seat-back Self-Help (Pouch/Pocket)	223
Underseat Self-Help	190
Seat Meal-tray Self-Help	158
Seat Armrest Self-Help	148
Carry-On Self-Help	124

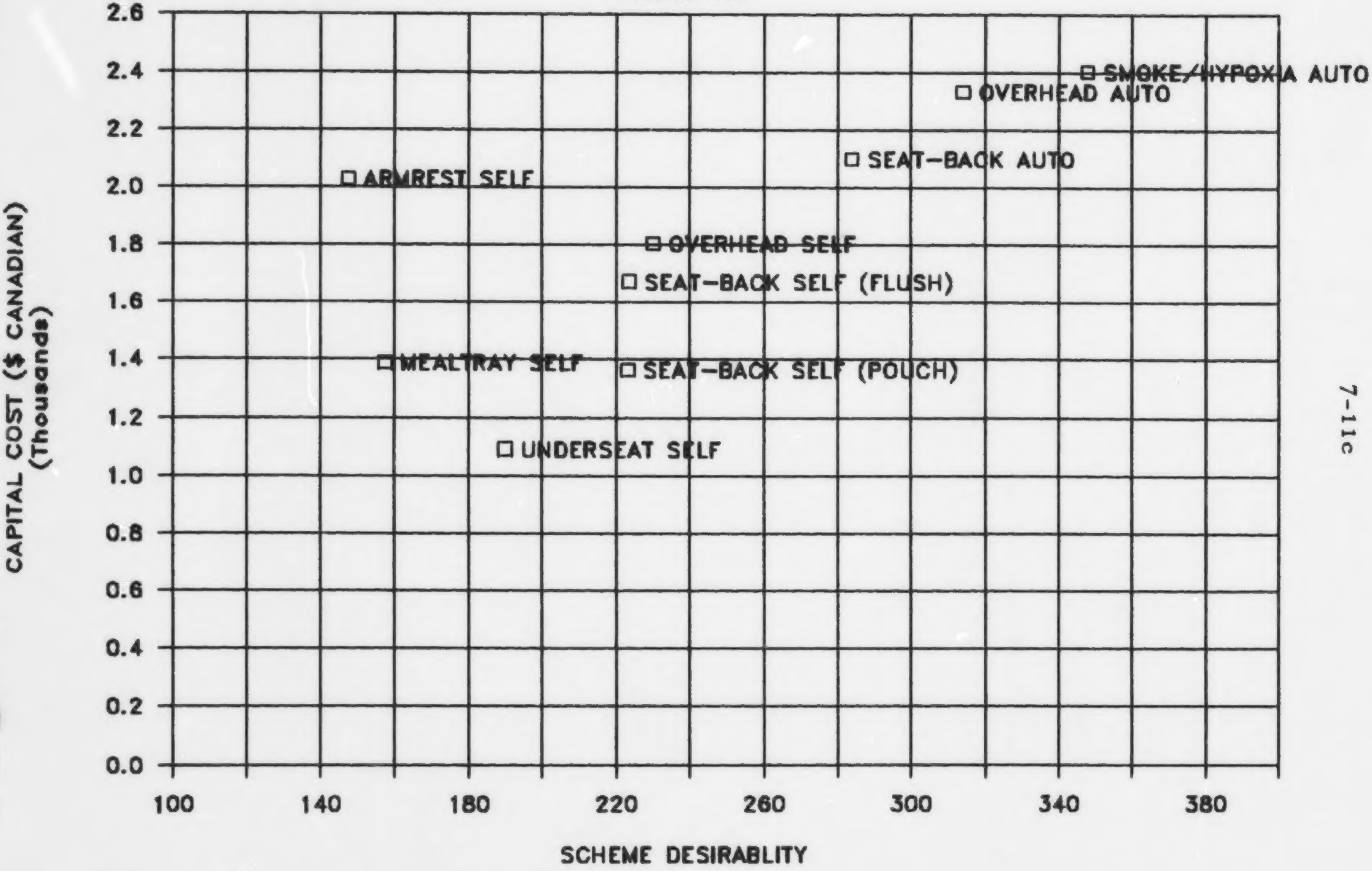
COST vs DESIRABILITY--SELF-CONTAINED

FIGURE 7.1



COST vs DESIRABILITY--NON SELF-CONTAINED

FIGURE 7.2



7.4 Summary

What is most interesting about the preceding analysis is how little the final rankings change with variations to both criteria and scenario rankings. Table 7.11 compares the various tests conducted. In all cases, the automatic overhead systems ranked first. In 9 out of 11 variants, the automatic seat-back system ranked second, and in 10 out of 11 variants, the self-help seat-back system ranked no worse than third.

It would therefore appear to the consultants that there is a clear preferential ranking of alternatives which would appear to remain consistent, independent of the type of evaluation of analysis conducted.

TABLE 7.11

COMPARATIVE SCENARIO RANKINGS

SCENARIO	RANKING ACCORDING TO TEST										
	A	B	C	D	E	F	G	H	I	J	K
1. Overhead Automatic	1	1	1	1	1	1	1	1	1	1	1
2. Seat-Automatic	2	2	2	2	3	2	2	2	3	2	2
3. Seat Pocket-Self	3	3	3	3	2	3	3	3	2	3	5
4. Seat Self	4	4	4	4	5	5	4	4	5	5	4
5. Under Seat-Self	5	5	5	5	4	4	5	5	4	4	6
6. Overhead-Self	n/a	6	n/a	n/a	n/a	n/a	6	6	6	6	3
7. Meal Tray-Self	6	7	6	6	6	6	7	7	7	7	7
8. Arm Rest-Self	7	8	8	7	8	8	9	8	9	9	8
9. Carry On-Self	8	9	7	8	7	7	8	9	8	8	9

TEST DEFINITIONS

A	Binary Analysis, large aircraft
B	Binary Analysis, small aircraft
C-F	Sensitivity Tests 1-4, large aircraft
G-J	Sensitivity Tests 1-4, small aircraft
K	Cost Sensitivity

8. APPLICABILITY OF SELECTED CONCEPTS

The following paragraphs discuss some of the applicable differences between short and long term PPBE implementation schemes.

Short term implementation schemes are defined as those which would likely be adopted by air-carriers should the PPBE requirement be obligated in the very near future. Long term implementation schemes are those which would likely be adopted by the air-carriers should the PPBE requirements be obligated over a longer time period and once PPBE development has reached maturity. The selection of an implementation scheme will be largely influenced by the investment justification for aging aircraft.

It is desirable to maximize the level of safety afforded to the passengers. In this context alone, the combined smoke/hypoxia automatic presentation overhead and seat-back schemes are the most favourable. As highlighted in Figure 7.1 and 7.2, increasing desirability is generally associated with increasing expenditure. The cost variance with respect to desirability is substantial since neither PPBE regulatory standards nor PPBE development have reached maturity. It is unlikely that air-carriers will commit to implementation schemes which require a large expenditure utilizing PPBE that may shortly become antiquated.

In identifying the short term and long term solutions, it is assumed that a certifiable PPBE exists, or will be available in the near future.

8.1 Short Term PPBE Implementation Schemes

A stowage/presentation scheme which is readily realized, has low costs, and without substantial reliance on speciality manufacturing would likely be implemented in the short term. The scheme selection would probably be dependent on the physical constraints of the candidate aircraft fleet. The carry-on scheme, underseat stowage, self-help scheme or seat-back 'pouch' scheme would likely be selected. This study identifies the seat-back 'pouch' or underseat schemes as proposed lower cost stowage/presentation schemes. As highlighted in this study, the passenger self-help carry-on scheme is highly undesirable with respect to all other schemes considered. Should the PPBE be of a non self-contained nature, the carry-on self-help scheme may not be certifiable. Without actual approved PPBE and implementation/functional testing, it is unclear that the proposed short term implementation schemes can meet final equipment specification requirements, and relevant airworthiness standards.

8.2 Long Term PPBE Implementation Schemes

Assuming the availability of smoke/hypoxia hybrid PPBE, it is unlikely that new aircraft would be manufactured with independent smoke/fire and hypoxia protection schemes based on a common or independent oxygen supply. The capital cost of a hybrid system would likely be less than the combined capital cost of two independent systems. The recurring costs, principally the weight penalty and maintenance/servicing would certainly be less for a hybrid system. Finally, the hybrid system scored highest with respect to desirability. The same methodology is applicable to aircraft which are scheduled for interior retrofits or major airframe inspections.

9. CONCLUSIONS

It is difficult to precisely state conclusions to a study which has evaluated stowage and presentation concepts for devices which are as yet undefined. PPBE development is still in the prototype stage. The viability of compact filtration based PPBEs is currently in question since an impasse with respect to carbon monoxide filtration is prevalent.

Although the development of PPBEs for aircraft use is being actively pursued by industry, and PPBE specification requirements are being developed concurrently, neither development nor legislation have attained a status which would allow for an accurate quantitative treatise. The study has therefore assumed a 'mean PPBE size envelope', either self-contained or non self-contained.

Nonetheless, certain conclusions can be reached which would seem to be independent of the specific device selected. These are discussed below.

9.1 Airworthiness

Although specific airworthiness requirements will vary from state to state, certification of any PPBE will require that it meet either current and/or future regulations, many of which are spelled out in some detail. Of particular importance is the requirement that PPBE be compatible with existing required equipment, and not interfere with, other mandatory equipment requirements, (e.g. life vests, oxygen systems, etc.). In light of the results of the concept evaluation, which suggest that relatively complex automatic systems are rated most favourably, care must be taken during the equipment design phase to ensure that various mandatory systems are mutually compatible.

9.2 Concept Definitions and Limitations

The survey of turbine powered transport category aircraft in air carrier service indicated that the correlation between aircraft sizes and types and PPBE implementation schemes is weak. Apart from overhead reach limitations, which prevent overhead manual systems from being installed on wide-bodied equipment, there is no single PPBE scheme whose desirability is significantly affected by aircraft type or size. The schemes' desirability with respect to ease of implementation is governed primarily by the existing space availability allowed by overhead panels and seats which is in turn related to the individual interior configuration, existing equipment and arrangement.

The passenger reach envelopes developed allowed for the identification of permissible stowage and presentation locations and possible constraints. Derivation of the reach envelopes is based on a 5 percentile women passenger being securely fastened in a seated position. One recent PPBE specification requires that a 2 percentile women be considered such that a broader range of passengers, especially children, be included. The 2 percentile requirement will decrease the reach envelope size, therefore making automatic systems somewhat more attractive, but otherwise does not introduce significant added constraints to the various implementation schemes.

One potentially critical factor, however, is the requirement that a secondary means of accessing the PPBE enclosure be required. This ruling can pose severe constraints depending on its interpretation; should the interpretation require this task to be executed by a 2 or 5 percentile women in a seated position, the overhead presentation schemes' feasibility would be questionable.

In all, ten potential stowage/presentation concepts were selected for further analysis. Automatic, self-help and carry-on systems were addressed, and possible locations included overhead, seat-back, armrest, meal-tray, and under-seat installations.

9.3 Functional and Physical Constraints

The various systems were assessed with regard to functional constraints, including susceptibility to pilferage and damage, the likelihood of global donning in a limited time period, scenario exclusivity, the minimization of additional tasking to the cabin crew, and the minimization of both physical and functional interference with other passengers and existing aircraft systems.

Pilferage and damage due to tampering will be prevalent when the PPBE are exposed and in sight of the passengers. For stowed schemes, it is possible to install an annunciation device which is activated when the PPBE is dislodged. This form of annunciation coupled with warning placards could be applied to life vest stowage as well. Curbing pilferage is notably difficult for the passenger carry-on scheme. Inadvertent damage is most likely for schemes which are located in existing aircraft systems which are frequently handled by passengers such as armrests, meal-trays, and external seat-pouches. 'Hardening' the enclosures will not necessarily alleviate this problem. From an operational standpoint, reduction of pilferage and damage is best accomplished by judicious location of PPBE.

Current PPBE specifications stipulate a maximum recognition to PPBE donned time of 10 seconds. This requirement is common to the automatic presentation hypoxia systems presently in use. There was no data available at the time of this study to investigate quantitatively the time periods associated with retrieving PPBE from differing locations. However, it is intuitively doubtful whether the action of reaching overhead or under a forward seat will result in a significant time differential. The most significant time consumption will result from the passengers recognizing the need of a PPBE, the mental recall as to the location of the stowed device, releasing the device from its stowage container and donning the device. The automatic presentation systems minimize the global donning time significantly; whether a self-help system can satisfy this requirement is uncertain. The 10 second recognition to donned requirement for a self-help scheme requires further consideration.

The deployment and annunciation controls should be located in close proximity to cabin crew stations such as to minimize cabin crew tasking. The automatic presentation systems will reduce crew tasking since passengers are required to address simpler and more obvious recognition and donning procedures.

Combined smoke/hypoxia units are desirable in that they address a broader range of possible emergency scenarios. In addition, a single dual purpose system is also conducive to lower overall weight penalties, smaller overall space requirements and lower costs associated with servicing and inspection.

The inspectability and serviceability status are characteristics which are considered primarily dependent on the design of the PPBE itself and its immediate encapsulating enclosure. It is difficult to conceive of a stowage enclosure which detects a system failure such as leakage without data particular to the specific PPBE. Should the PPBE design incorporate a 'flag' colour change indicating failure, the stowage enclosure should certainly not degrade this feature. All stowage schemes identified are considered to have equal potential in satisfying this requirement.

From a human behavioural point-of-view, it is apparent that the automatic presentation schemes are far more desirable than self-help schemes, particularly when considering factors such as potential for human error which may lead to panic in an emergency situation. Furthermore the automatic schemes would also be more suitable for the "special population" who have a variety of limitations that will affect their ability to access and use a PPBE unit.

9.4 Cost Analysis

The cost for implementation of any given scheme was found to be principally influenced by the existing PSU panel, baggage bin geometry and seat characteristics. The existing movable PSU panels in the subject aircraft cannot be easily modified to house an independent PPBE system. The PPBE, if mounted overhead must also be located on movable panels such that reach/presentation envelopes are satisfied for differing seat configurations. The PSU panels must therefore be completely replaced in almost all cases. The overhead systems are therefore generally more costly to implement than seat based PPBE systems. Recurring costs will be higher for seat based systems since they are more susceptible to pilferage, tampering, inadvertent damage and seating modifications.

The unit cost of a PPBE is estimated to be C$300, based on a current prototype self-contained gaseous unit. On that basis, the implementation costs per seat, including an allowance for 10% redundancy, range from about $500 for a simple carry-on system, to about $2,500 for a complex overhead automatic presentation system. Implementation costs are defined to include all non-recurring cost elements.

Annual recurring costs (servicing, inspection, pilferage, etc.) are estimated to vary between $150 and $200 per seat for all systems, without including any interest or capital charges, or depreciation. Depending on individual airline's accounting system, these could add an additional $50-$250 annual burden per seat (total of 8-13 cents per seat-hour for 3,000 hours annual utilization).

9.5 System Evaluation

Binary decision theory was used to evaluate all concepts against five critical mutually-exclusive criteria:

- Recognition and Access Time.
- Usability and Inspectability.
- Crew Tasking.
- Installation Costs.
- Recurring Costs.

The two automatic systems (overhead, and seat-back) ranked first and second by a clear margin, despite being the most expensive. The carry-on scheme ranked last, despite being the least expensive. Various self-help concepts ranked in between the two extremes.

A series of sensitivity tests was run to determine whether or not the results varied with reasonable changes to the inputs. Eleven tests were computed, and the overhead automatic system ranked first in all of them. The automatic seat-back system ranked second in 9 of 11 trials, while the self-help seat pocket system ranked no worse then third in 10 of 11 trials.

9.6 Short and Long Term Implementation Schemes

Short and long term PPBE implementation schemes were examined. Schemes which have low costs, are readily recognized, and do not have a requirement for speciality manufacturing would likely be implemented in the short term. These would include the carry-on, the underseat stowage or the seat-back pouch self-help schemes.

In the long term, smoke/hypoxia hybrid PPBE systems, if available, would likely be implemented in new aircraft.

9.7 Future Study Considerations

So as to allow for a complete realization of the subject study objectives, the following supplemental study is believed to be warranted; the subject study focused primarily on PPBE installation aspects including economic viability. The PPBEs identified during the equipment survey were restricted by prototype or prototype PPBE data available at the time the report was compiled. As a result, the quantitative treatise of PPBE in this study was somewhat restricted to self-contained and non self-contained breathable gas types. It is likely that near future development of filtration based PPBE and hybrid smoke/hypoxia systems may potentially offer better functional characteristics, greater ease of implementation and preferred economics. A follow-on study examining the aforementioned systems in detail is considered desirable.

Once a more definitive PPBE design and standard is developed, it is believed that a more detailed and realistic study focusing on the developed PPBE would be appropriate. In addition, a detailed study of aircraft operators and aircraft interiors to determine the preferred stowage location is considered desirable. Based on the above a more detailed and realistic cost analysis can also be done.

Most current draft specifications for PPBE require a recognition to don time of 10 seconds. Whether this requirement can be realized by auto-presentation and non auto-presentation systems is questionable. The methodology establishing a 10 second to don time requirement for PPBE should be reviewed in light of the rigorous restraints the requirement imposes on the PPBE design as well as installation considerations. Conversely, consideration of the changes required to the PPBE design to offset the don time shortcoming in conjunction with stowage means could be meaningful.

Finally, of a more fundamental nature; the study is founded on a means to effectively allow passengers added time to evacuate an aircraft. How the PPBE concept compares with other methods such as water sprinkling system or a total flood fire extinguishing system with respect to installation and economic considerations/effects is a valid study objective. It would probably be a sensible follow-up to the current studies being undertaken by other Canadian firms on crash-fire-rescue, and light aircraft crashworthiness.

APPENDIX "A"

AIRWORTHINESS STANDARDS INCLUDING FAR'S, JAR'S AND ANO'S

FAR 25 Airworthiness Standards: Transport Category Airplanes (Amendments 1- 61 Jan. 1987)

a) Emergency Landing Conditions (FAR 25.561 (c))

This paragraph provides for the restraint loads for each article of mass and is self explanatory.

b) Materials (FAR 25.603)

This section defines the criteria for material used for installation if their failure could affect safety.

c) Fabrication Methods (FAR 25.605)

The manufacturer must produce sound structural components.

d) Accessibility Provisions (FAR 25.611)

This requirement is primarily intended for the inspection of structure and therefore if the installation of the PPBE may interfere with such inspections then provisions will be necessary so that this requirement can be satisfied. It is not likely that the structural requirements for the PPBE will, by themselves, require any particular structural inspection provisions.

e) Material Strength Properties and Design Values (FAR 25.613)

If the materials used for the installation of the PPBE's have a known characteristic then this requirement is self explanatory.

f) **Seats, Berths, Safety Belts and Harnesses (FAR 25.785)**

The installation of PPBE must take into consideration these requirements in that either the PPBE installation will need to be designed so as to not present a hazard to the passenger should the head contact it as a result of an emergency landing (FAR 25.561) or the installation shall need additional protection to provide the same degree of safety to the passenger. The requirement applies to all stations where a PPBE will be required.

g) **Stowage Compartments (FAR 25.787)**

Compartments must contain their contents under the landing loads so that their contents cannot become a hazard. This requirement does not apply to underseat stowage provisions which is covered by Operational Requirements.

h) **Retention of Items of Mass in Passenger and Crew Compartments and Galleys (FAR 25.789)**

No item of mass in the passenger compartment may become a hazard if it shifts under the maximum design load factors or during emergency landing conditions. This requirement necessitates that the installation container, holding the PPBE, shall continue to contain the PPBE after these loads are applied to the airplane. This requirement does not apply if the mass of the PPBE under the applied loads are sufficiently low so as to not cause injury to the passenger should the person be hit by same.

i) Emergency Evacuation (FAR 25.803 (c))

The maximum evacuation time of 90 seconds for the complete airplane may have to be reconsidered if the use of the PPBE's warrant or require such. For the purpose of this study it is assumed that the 90 second requirement will be maintained and as such the installation options for the PPBE units need to take this into consideration. FAR 25.803(c) does not address need for safety equipment such as life vests to be worn, however even if the demonstration did not cater for the use of PPBE's, the operational requirement of the FAA, FAR 121.291, will likely require the demonstration.

j) Compartment Interiors (FAR 25.853)

This paragraph defines criteria for materials within the passenger compartments. These are self explanatory.

k) Function and Installation (FAR 25.1301)

Equipment must be labelled according to its intended function, be installed according to it's limitations and properly function when installed. This requirement states that the installed PPBE function shall not be affected by the type of installation that has been provided (environmental temperatures, vibration and aircraft loading etc., will remain within the design parameters of the PPBE). Therefore, if the PPBE is functional and serviceable, then the installation will not affect that state of reliability.

l) Equipment, Systems and Installations (FAR 25.1309)

Equipment must perform its function under any foreseeable operating condition. There is much advisory literature on the interpretation and application of this requirement. In essence, it required that no single or multiple related failure of the installation shall prevent the availability of the PPBE This requirement does not eliminate the use of a manual means of obtaining the PPBE, but rather, if the prime system malfunctions, it does not demand that the proposed time of ten seconds for donning be met under all possible failure modes. The requirement does expect that, if multiple related failures deny ready access, then no hazard will result to the user (the user need not be as healthy as if the system had functioned properly the first time but the persons health should not deteriorate to the point of non-survival). This requirement does not address PPBE unless such a device is required by operating requirement. In this case the installation of the PPBE will be affected by it.

m) Circuit Protective Devices (FAR 25.1357/1359)

If an electrical circuit is involved for the installation of PPBE then this requirement must be considered. The requirement is self explanatory.

n) Safety Equipment - General (FAR 25.1411(a),(b))

Since it is assumed that the cabin crew will be provided with the same level of protection as the passengers, the PPBE. system must be readily available to them and allow them to perform their duties including using the PA system. Stowage provisions must be arranged so that the equipment is readily accessible and its location is obvious and it must be protected from inadvertent damage. These specific design requirements speak to the installation of the PPBE and not to any other factor that may be imposed on access time either in conjunction with or in priority to, other devices. However, operating requirements may impose time and/or priority in the various use of devices. This requirement should be read in conjunction with FAR 121.291(c), 121.309(f), 121.318(b) and 121.319.

o) Chemical Oxygen Generators (FAR 25.1450)

Governs the design and installation requirements of a chemical oxygen generating system installed in an aircraft. It states that the surface temperatures developed during operation shall not create a hazard to the aircraft or to the passengers, and requires a pressure relief to avoid hazards, and if portable and capable of sustained operation by successive replacement of generator elements, it must be placarded to show rate of oxygen flow, duration of flow and a warning that the replaceable element may be hot.

p) Protection of Oxygen Equipment from Rupture (FAR 25.1453)

If aircraft oxygen tanks, lines and/or shut off means are used by the PPBE then these items, to the extent that they pertain to the PPBE system, need to be protected against unsafe temperatures and where the probability of rupture may exist during a crash landing the consequences are to be minimized. This will have to be taken into consideration in the decision as to where best to stow this particular type of PPBE

q) Equipment Standards for the Oxygen Distribution System (FAR.1445)

This will have to be maintained should the PPBE be an integral part of the aircraft's oxygen system.

r) Equipment Standards for Oxygen Dispensing Units (FAR 25.1447)

This requirement is not directly related to the PPBE installation question but there are aspects of this paragraph which should be considered, i.e. 25.1447(c) (3), (4) requires dispensing equipment in each washroom and in each lavatory, if separate from the washroom, and a separate item of portable equipment must be available for each cabin attendant.

s) Maintenance Manual (FAR 25.1529)

The requirement does not require that the designer supply aeroplane maintenance information to products or appliances which are not interfaced with the aeroplane. Therefore, if the PPBE is not an integral part of the aeroplane, no maintenance information need be provided within the intent of the requirement. However, except for the carry-on PPBE unit, the installation for the PPBE's do constitute part of the aeroplane and therefore they must be included within the maintenance requirement; this would include any inspection etc., required in order to ensure the continuing airworthiness of the installation system.

Other maintenance requirements for the PPBE and for its installation may be imposed via the operating requirements such as defined in the Canadian Airworthiness Manual, the ANO's, or in FAR Operating Rules.

t) Safety Equipment (FAR 25.1561)

This pertains to the marking of emergency equipment so that everyone knows where it is and what to do with it. Stowage provisions for required equipment must be conspicuously marked to identify the contents and facilitate the ease of removal of the equipment.

European Design Standards (Joint Airworthiness Requirements JAR 25 (Mar 86)

a) Precaution Against Injury (JAR 25X.1360)

Electrical systems must be designed to minimize electrical shock to crewmembers, passengers or to service personnel. This requirement would apply to a PPBE installation if the installation was to be approved by the European Community. However, it only applies if the installation involves an electrical circuit.

Temperature rise of any part, to be handled by flight crew, must not be such as to cause a dangerous inadvertent movement or an injury. The requirement is self explanatory.

b) Electrical Systems (JAR 25X.1362)

Electrical supplies for emergency conditions must be independent so that an emergency drill may be carried out after an emergency landing or ditching, and the design must be such that the risk of causing a fire under these conditions is minimal.

If an electrical system is used to provide PPBE units to the occupants or crew of the aircraft, then this requirement would apply in that, the system which controls the availability of the PPBE, must be designed to ensure that it continues to function after the above conditions are imposed while minimizing the risk of fire.

Canadian Government Aircraft Operational Requirements (Air Navigation Orders [ANO])

a) Aircraft Seats, Safety Belts and Safety Harness (ANO II #2)

This ANO requires safety belts or safety harnesses be supplied for each person in the aircraft other than infants (persons under two years of age) and such equipment shall be worn by the passengers during take-off and landing and at other times when directed by the crew. Infants shall be securely restrained in the arms of an adult.

This operational requirement poses a difficult installation problem to the installers of the PPBE, since such equipment will be required by the infant as well as by the adult. It could mean that specific seat allocation will be necessary for those passengers who have boarded with infants and such locations will require a dual installation regardless of whether it is self-help or automatic. It is questionable if this requirement for an infant can be considered in a similar manner as the additional 10% criteria, which is used in the case of oxygen masks. It is doubtful that the circumstances in which the PPBE units would be used would allow for cabin distribution by the crew, if the infants were scattered randomly throughout the cabin.

b) Life Saving Equipment (ANO II #8)

This requirement implies that for aircraft operating over water, certain types of life saving equipment must be carried including a life jacket for each person on board. Furthermore, the life jackets must be stowed in such manner as to be readily accessible to those who would use them.

Therefore, when considering the installation of a PPBE, if consideration is given to the moving of life jackets to locations other than those already approved, then this requirement will need to be taken into consideration. It would not be sufficient to merely remove the life jacket and replace them with PPBE's without consideration as to where it will be moved to.

c) Oxygen Equipment (ANO II #9)

This requirement provides for the provision and amount of oxygen required for flight crew members and passengers and, for first aid oxygen and protective breathing equipment for commercial operations.

When considering the installation of PPBE units, this requirement will necessitate of provision being made for flight crew members in the case where the PPBE is a part of the aircraft oxygen system. Additional oxygen supply is required to cater for time spent below normal oxygen requirement heights when PPBE units are donned. This would also include the period on the ground while waiting for evacuation to commence.

d) Restraint of Carry-on Baggage (ANO VII #4)

This Order states that all baggage must be stowed during takeoff, landing and during in-flight turbulence, either in the overhead clothing rack or under a passenger seat. The overhead stowage compartment must be approved by the Minister. The underseat stowage means must be able to restrain the baggage when subject to both forward and sideward gravity forces and, not allow the baggage to obstruct the accessibility of any safety equipment.

This Order applies to the installation of a PPBE, if such installation would be in conflict with the area under the passenger seat where baggage is normally stowed. If the installation of the PPBE is such so that underseat baggage will interfere with the PPBE accessibility, then one of them must be moved. If the underseat stowage area is removed, then other means of stowing this baggage will need to be considered.

United States Government Operational Design Standards

a) Emergency Equipment (FAR 91.193)

No person can operate an airplane unless it is equipped with the emergency equipment listed below (PPBE is not mentioned), but if such an item was added then item (i) below would apply. Such an item as a PPBE would probably be added as a separate item under FAR 121.303 for commercial operation of large aircraft.

(i) Each item of equipment:

1) must be inspected regularly in accordance with FAR 91.217 to ensure its serviceability and immediate readiness for use.
2) must be readily accessible to the crew.
3) must clearly indicate its method of operation.
4) when carried in a compartment or container, must have the compartment or container marked as to contents and date of last inspection.

b) Demonstration of Emergency Evacuation (FAR 121.291)

This addresses an operator having to demonstrate a live evacuation for the procedures that are in place for the crew members, for each type or model of aircraft that he operates. Unless certain circumstances prevail, the principle can also apply and has been applied where there is a change in those factors which might affect the procedures or time to be evacuated. Certainly the introduction of PPBE could be an example of this and therefore in considering the impact of PPBE on air carriers, the cost of this demonstration should be taken into consideration.

Appendix D to FAR 121 describes the nature of emergency evacuation required by 121.291.

c) Airplane Instruments and Equipment (FAR 121.303)

All equipment required by this Subpart, which includes the oxygen systems shall be approved and installed in accordance with the airworthiness requirements applicable to them. If a PPBE system was made mandatory for use in large airplanes, and since there are no specific design standards for their installation presently stated in such documents, then it is likely that their installation would be considered along those lines applied to the oxygen systems. Therefore FAR 25.1441, CFAR 25.1441, FAR 25.1309 and CFAR 25.1309 would be some of the design requirements applied. However, the conflict in the installation of several devices, all of which may have retrieval times applied to them is not provided for via this requirement.

d) Emergency Equipment (FAR 121.309)

Each item of emergency equipment must be inspected regularly to ensure its serviceability and immediate readiness to perform its intended function. It must be readily accessible to crew and passengers, must be clearly identified and clearly marked to indicate method of operation and, if carried in a compartment or container, the compartment or container must be marked as to content and date of last inspection. This requirement also calls for megaphones which will be readily accessible to the crew members to direct emergency evacuation. If the installation of a PPBE is made mandatory, and if it is included within this specific section of FAR 121.309, then it will have to be inspected as indicated.

e) Material for Compartment Interiors (FAR 121.312)

The material used to install a PPBE will have to meet the FAR 25.853 requirement. (effective 20 Aug 1986). The requirement is self explanatory.

f) Public Address System (FAR 121.318)

An airplane with more than 19 passengers must be fitted with a public address system. This must be accessible by a certain number of flight attendant stations near each floor level emergency exit and must be accessible within ten seconds by the flight attendant. The installation of the PPBE for the flight attendant cannot be in conflict with this requirement but it is not necessary to consider that both events are initiated at the same time.

g) Crewmember Interphone System (FAR 121.319)

No person may operate an airplane, with a seating capacity of more than 19, unless there is a interphone system. Outlets must be present in each passenger compartment and each galley not on the main passenger deck. The interphone system must be accessible from at least one normal flight attendant station and capable of operation within ten seconds. For large turbo jets, there are more location requirements. As per FAR 121.318, the PPBE installation for the flight crew member can not distract from this requirement but all events should not be considered as initiated at same instant of time.

h) Supplemental Oxygen for Emergency Descent and for First Aid; Turbine Engine Powered Airplanes with Pressurization (FAR 121.333)

- Use of oxygen masks by flight crew members.
- Passenger cabin occupants.
- Passenger briefings before flight.

Although not directly applicable to PPBE, these three paragraphs will have to be reworked to provide for the PPBE at altitude both for crew and passenger. If PPBE is not combined with the oxygen mask, then this situation will become difficult. How is it best to provide, physically, for both at the same time? If they are a combined system then it is possible that additional oxygen will be required in order to provide smoke protection at those altitudes where oxygen is not normally required.

i) Emergency and Emergency Evacuation Duties (FAR 121.397)

This pertains to the need for the operator to demonstrate, for each type and model of aircraft, that the duties assigned to each crew member in an emergency are realistic and meet any reasonable circumstance including incapacitation of individual crew members.

Installation of PPBE units will require additional training for the crew members as well as additional duties.

APPENDIX "B"

MATHEMATICAL QUALIFICATION OF REACH ENVELOPES

Seated body dimension data taken for 5th percentile women, from "Human Engineering Laboratory Detachment. U.S. army missile command, Redstone Arsenal, Alabama and MIL-STD-1472."

"Limiting Dimension - Limiting Dimension (reaching distance, control movement, displays, test points, handrails, etc.) which restrict or are limited by extension of the body shall be based upon 5th percentile values for applicable body dimensions". Ref MIL-STD-1472B 5.6.3.3.

FIGURE 1

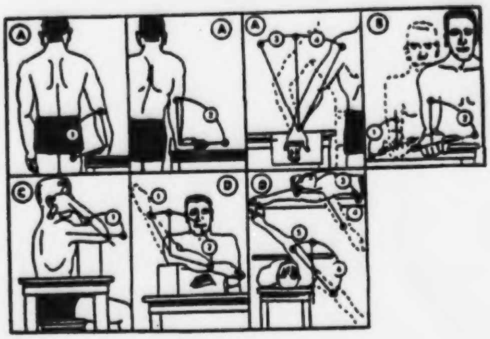


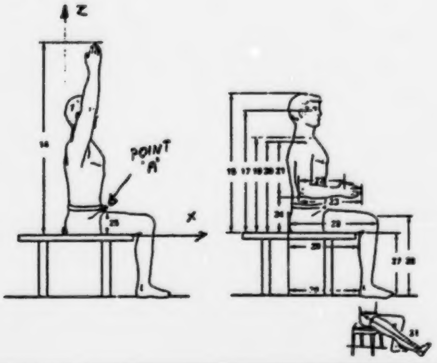
TABLE XXXVIII. HUMAN RANGE OF MOTION*

Body Member and Movement	Lower Limit (deg)	Upper Limit (deg)	Average (deg)
A Wrist			
1 Flexion	78	102	90
2 Extension	86	112	99
3 Abduction	40	54	47
4 Adduction	18	36	27
B Forearm			
1 Supination	91	135	113
2 Pronation	53	101	77
C Elbow			
1 Flexion	132	152	142
D Shoulder			
1 Lateral rotation	21	47	34
2 Medial rotation	75	119	97
3 Extension	47	75	61
4 Flexion	176	190	183
5 Adduction	39	57	48
6 Abduction	117	151	134

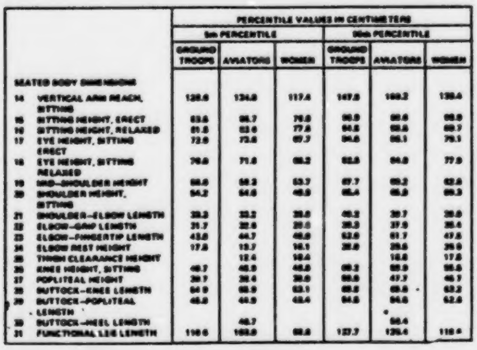
*These dimensions are based on the nude body. The ranges are larger than can be expected when personnel are clothed.

BODY DIMENSIONS

FIGURE 2

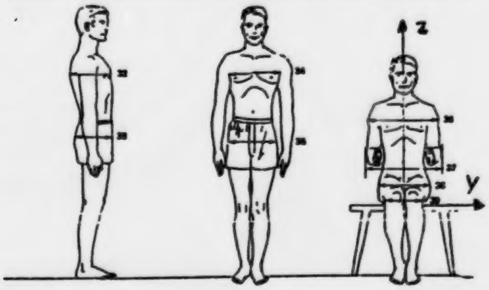


5th PERCENTILE			
DIM	WOMEN [in]	DIM	WOMEN [in]
14	46.22	23	15.75
15	31.10	24	6.34
16	30.51	25	4.09
17	26.65	26	18.46
18	26.06	27	14.96
19	21.14	28	20.91
20	19.64	29	17.09
21	12.13	30	–
22	11.65	31	39.21

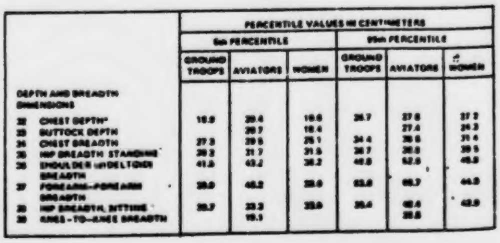


	PERCENTILE VALUES IN CENTIMETERS					
	5th PERCENTILE			95th PERCENTILE		
	GROUND TROOPS	AVIATORS	WOMEN	GROUND TROOPS	AVIATORS	WOMEN
SEATED BODY DIMENSIONS						
14 VERTICAL ARM REACH, SITTING	128.6	134.8	117.4	147.8	160.2	138.4
15 SITTING HEIGHT, ERECT	83.6	[illegible]	79.0	[illegible]	[illegible]	[illegible]
16 SITTING HEIGHT, RELAXED	81.5	[illegible]	77.5	[illegible]	[illegible]	[illegible]
17 EYE HEIGHT, SITTING ERECT	72.9	73.6	67.7	[illegible]	[illegible]	79.1
18 EYE HEIGHT, SITTING RELAXED	70.6	71.6	66.2	[illegible]	[illegible]	77.9
19 MID-SHOULDER HEIGHT	[illegible]	59.2	53.7	67.7	[illegible]	[illegible]
20 SHOULDER HEIGHT, SITTING	54.2	54.6	[illegible]	[illegible]	[illegible]	[illegible]
21 SHOULDER-ELBOW LENGTH	[illegible]	33.2	[illegible]	[illegible]	39.7	[illegible]
22 ELBOW-GRIP LENGTH	31.7	[illegible]	[illegible]	[illegible]	37.9	[illegible]
23 ELBOW-FINGERTIP LENGTH	43.6	44.7	[illegible]	[illegible]	51.7	47.5
24 ELBOW REST HEIGHT	17.5	[illegible]	16.1	[illegible]	[illegible]	[illegible]
25 THIGH CLEARANCE HEIGHT		12.4	10.4		[illegible]	17.5
26 KNEE HEIGHT, SITTING	48.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27 POPLITEAL HEIGHT	39.7	[illegible]	[illegible]	[illegible]	47.7	[illegible]
28 BUTTOCK-KNEE LENGTH	54.9	[illegible]	53.1	[illegible]	[illegible]	[illegible]
29 BUTTOCK-POPLITEAL LENGTH	[illegible]	[illegible]	43.4	[illegible]	[illegible]	[illegible]
30 BUTTOCK-HEEL LENGTH		[illegible]			[illegible]	
31 FUNCTIONAL LEG LENGTH	110.6	[illegible]	[illegible]	127.7	[illegible]	[illegible]

FIGURE 3



5-th PER.	
DIM	WOMEN [in]
32	7.72
33	7.24
34	9.88
35	12.4
36	15.04
37	12.99
38	12.99
39	–



	PERCENTILE VALUES IN CENTIMETERS					
	5th PERCENTILE			95th PERCENTILE		
	GROUND TROOPS	AVIATORS	WOMEN	GROUND TROOPS	AVIATORS	WOMEN
DEPTH AND BREADTH DIMENSIONS						
32 CHEST DEPTH*	[illegible]	20.4	19.6	[illegible]	27.8	[illegible]
33 BUTTOCK DEPTH		[illegible]	18.4		27.4	[illegible]
34 CHEST BREADTH	27.3	[illegible]	25.1	34.4	[illegible]	[illegible]
35 HIP BREADTH, STANDING	[illegible]	31.7	[illegible]	[illegible]	[illegible]	[illegible]
36 SHOULDER (BIDELTOID) BREADTH	[illegible]	[illegible]	38.2	[illegible]	[illegible]	[illegible]
37 FOREARM-FOREARM BREADTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
38 HIP BREADTH, SITTING	[illegible]	33.3	[illegible]	[illegible]	[illegible]	[illegible]
39 KNEE-TO-KNEE BREADTH		19.1			[illegible]	

EQUATIONS OF FUNCTIONAL REACH ENVELOPE

Following assumptions are made:

- Upper part of the body can rotate around point "A" (Fig. 2) in XZ plane 0-75^o (from Z axis)

  $b = 0^o / 75^o$

- Arms can rotate around shoulders

  $p = 0 / 180^o$ from Z^1 in ZX plane

  $th = -48^o / 134^o$ around Z^1 in X^1Y^1 plane* (left arm) [Fig. 1 (-5) (-6)] Since movemement of both arms will define functional reach envelope, lower limit for th is taken Y = 0

*$X^1Y^1Z^1$ frame of reference is obtained by:

- 1^o rotation XYZ around "A" point (Y) by angle 6
- 2^o translation to the shoulder point

- There is no rotation of the upper part of the body in YZ plane. This movement may be limited due to the fact of wearing seat belts.

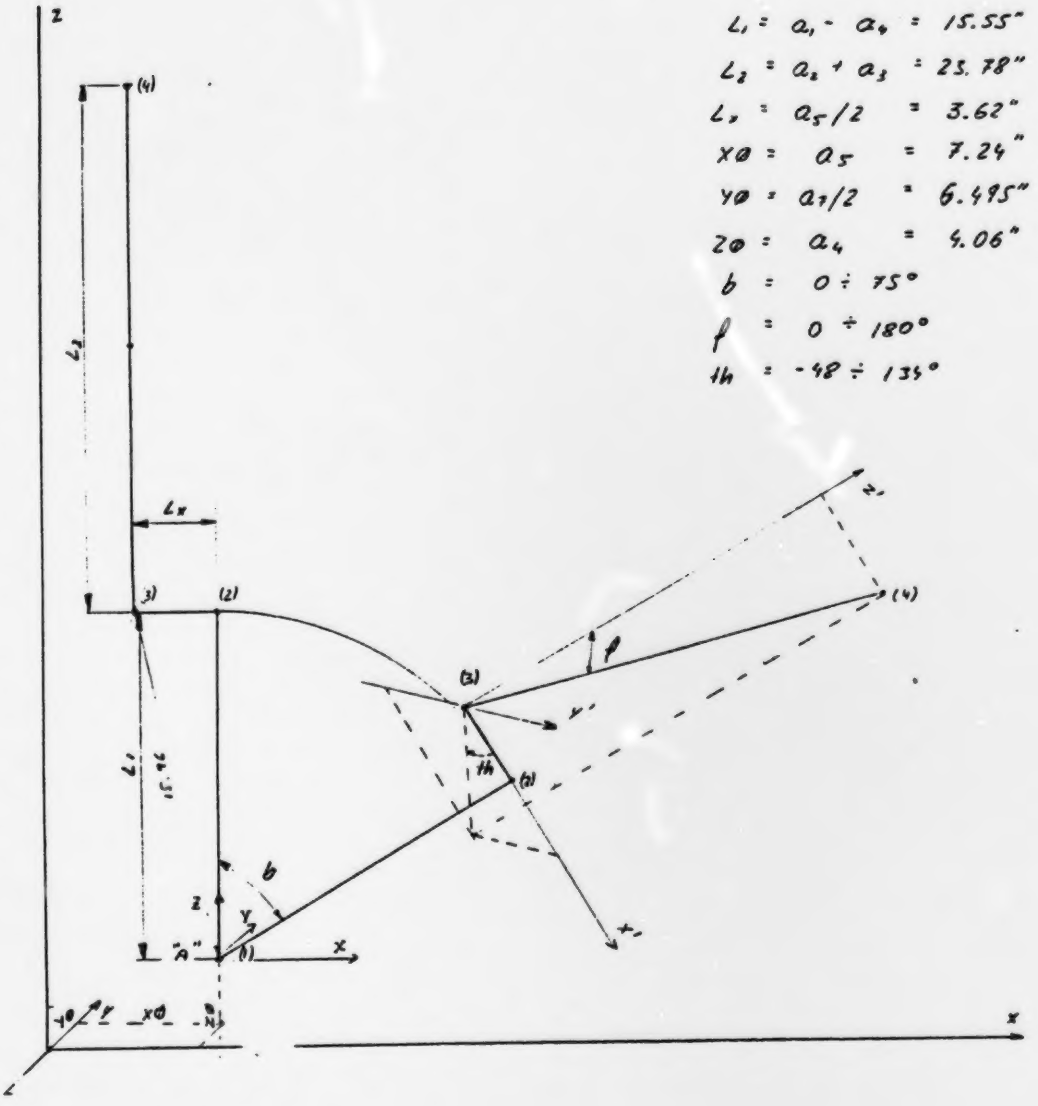
- Point "A" does not change position in XYZ frame of reference.

- Each point inside envelope can be reach due to the fact, that rotation around elbow is not included in the equations.

Following dimensions (5th percentile women) are used Fig. (1/3).

(a_1) shoulder height - 19.64"
(a_2) elbow - griplength - 11.65"
(a_3) shoulder - elbow length - 12.13"
(a_4) thigh height - 4.06"
(a_5) buttock depth - 7.24"
(a_6) hip break sitting - 12.99"
(a_7) shoulder to shoulder - 12.99"

FIGURE 4



$L_1 = a_1 - a_4 = 15.55"$

$L_2 = a_2 + a_3 = 23.78"$

$L_x = a_5/2 = 3.62"$

$X0 = a_5 = 7.24"$

$Y0 = a_7/2 = 6.495"$

$Z0 = a_4 = 4.06"$

$b = 0 \div 75°$

$f = 0 \div 180°$

$th = -48 \div 135°$

POSITION OF POINT (2) FIG 4

$x = l_1 \sin(b)$

$Y = 0$

$Z = l_1 \cos(b)$ WHERE $x = X - x0$

$y = Y - y0$

$z = Z - z0$

$x0, y0, z0$ - POINT "A" CORDS.

POSITION OF POINT (3) FIG 4

$x = l_1 \sin b - l_x \cos b$

$y = 0$

$z = l_1 \cos b + l_x \sin b$

POSITION OF POINT (4) FIG 4

$x' = l_2 \sin f \cos th$ $z = z' \cos b - x' \sin b$

$y' = l_2 \sin f \sin th$ where $x = z' \sin b + x' \cos b$

$z' = l_2 \cos f$ $y = y'$

$x = l_2 \sin f \cos th \cos b + l_2 \cos f \sin b + l_1 \sin b - l_x \cos b$

$y = l_2 \sin f \sin th$

$Z = l_2 \cos f \cos b - l_2 \sin f \cos th \sin b + l_1 \cos b + l_x \sin b$

① $x = \sin b \, (l_2 \cos f + l_1) + \cos b \, (l_2 \sin f \cos th - l_x)$

② $y = l_2 \sin f \sin th$

③ $z = \cos b \, (l_2 \cos f + l_1) - \sin b \, (l_2 \cos th \sin f - l_x)$

SUBSTITUTE IN ① AND ③

(3a) $A = l_2 \cos\phi + l_1$ (3b) $B = l_2 \sin\phi \cos\theta - l_x$

$x = A \sin b + B \cos b$

$z = A \cos b - B \sin b$

SOLVING FOR A AND B

④ $A = x \sin b + z \cos b$

⑤ $B = x \cos b - z \sin b$

FROM (3a) AND ④

$$\cos\phi = \frac{x \sin b + z \cos b - l_1}{l_2}$$

⑥ $l_2 \sin\phi = \sqrt{l_2^2 - (x \sin b + z \cos b - l_1)^2}$

FROM (3b) AND ⑤

⑦ $$\sin\theta = \frac{\sqrt{l_2^2 \sin^2\phi - (x \cos b - z \sin b + l_x)^2}}{l_2 \sin\psi}$$

SUBSTITUTING ⑦ AND ⑥ IN ②

⑧ $$y = \sqrt{l_2^2 - (x \sin b + z \cos b - l_1)^2 - (x \cos b - z \sin b + l_x)^2}$$

or

$$\left[x - (l_1 \sin b - l_x \cos \beta)\right]^2 + \left[z - (l_1 \cos \beta + l_x \sin \beta)\right]^2 + y^2 = l_2^2$$

or

⑨ $$(x - l \sin b')^2 + (z - l \cos b')^2 + y^2 = l_2^2$$

where $l = \sqrt{l_1^2 + l_x^2}$

$b' = -13.10489^\circ \div 61.8951^\circ$

$x = X - X0$

$y = Y - Y0$

$z = Z - Z0$

⑩ $$(X - X0 - l \sin b')^2 + (Z - Z0 - l \cos b')^2 + (Y - Y0) = l_2^2$$

EQUATION ⑩ IS USED TO GENERATE PLOTS OF FUNCTIONAL REACH ENVELOPE FOR $X \geqslant 0$.

```
' This program genarates plots in XY plane for inreasing Z from -11
' (11" in below seat level) with increasment 2.5" by creating AutoCad
' interchange file ZZZ.DXF.
' Plot for each Z is  generated at elevation equal to Z.


1 OPEN "ZZZ.DXF" FOR APPEND AS #1
2 SCREEN 2
5 P=3.1415926#/180
   Y0=6.495:X0=7.24:Z0=4.09
10 L2=23.78:L=(15.55^2+3.62^2)^.5
15 BU=61.8951007#*P:BL=-13.104899#*P
    K=10
      Z=-11-4.09
30        FLAG=1:FF=0:K=K+1:JJ=0
      X=-X0:FT=0
31       FL=0:CRT=0:YT=0:XT=0
         FOR B=BL TO BU STEP P*.5
           YY=L2^2-(X-L*SIN(B))^2-(Z-L*COS(B))^2
           IF YY<0 THEN GOTO 100
           Y=FLAG*YY^0.5
           IF Y^2>YT^2 THEN YT=Y:FL=1:XT=X:FF=1
           IF X=-X0 AND FL=1 THEN FLA=1

100      NEXT B

      LOCATE 2.1:PRINT X.Z
      IF FF=0 AND X>50 GOTO 200
      IF FF=1 AND FL=0 THEN
       Y=0:KK=FLAG:GOSUB 1000:FF=0:FLAG=-1*FLAG:IF FLAG=1 THEN GOTO 200
      END IF
      IF YT<-6.495 AND FT=0 THEN KK=1:Y=-6.495:GOSUB 1000:FT=1:GOTO 150

      IF YT>-6.495 AND FT=1 THEN KK=-1:Y=-6.495:GOSUB 1000:FT=0:GOTO 150


      IF FL=1 AND FT=0 THEN GOSUB 3000
150   IF FLA=1 AND FT=1 THEN FT=0:FLA=0:GOTO 200
      X=X+FLAG*2
      IF X<-X0 GOTO 200
      GOTO 31
200   JJ=2:GOSUB 3000
      Z=Z+2.5
      IF Z>45 GOTO 300
      GOTO 30
300   CLOSE:END

1000 XT=-KK*1000:FL=0:YT=Y:T=X
     FOR B=BL TO BU STEP P*.5
       XX=L2^2-Y^2-(Z-L*COS(B))^2
       IF XX<0 THEN GOTO 1100
       X=KK*XX^0.5+L*SIN(B)
      IF KK=1 THEN
       IF X>XT THEN XT=X:FL=1:YT=Y
      END IF
      IF KK=-1 THEN
       IF X<XT THEN XT=X:FL=1:YT=Y
      END IF
1100 NEXT B
     IF FL=1 THEN GOSUB 3000
     X=T
     RETURN
```

```
3000 PSET (XT*7.5+200,YT*3+100)
     LOCATE 1.1:PRINT XT,YT
     FL=0
      IF JJ=0 THEN
        PRINT #1."POLYLINE"
        PRINT #1,"  8"
        PRINT #1, K
        PRINT #1," 38"
        PRINT #1, Z+Z0
        PRINT #1," 66"
        PRINT #1,"  1"
        PRINT #1,"  0"
        JJ=1
       END IF
       IF JJ<=1 THEN
        PRINT #1,"VERTEX"
        PRINT #1,"  8"
        PRINT #1, K
        PRINT #1." 38"
        PRINT #1, Z+Z0
        PRINT #1," 10"
        PRINT #1, XT+X0
        PRINT #1," 20"
        PRINT #1, YT+Y0
        PRINT #1,"  0"
       END IF

       IF JJ=2 THEN

        PRINT #1,"SEQEND"
        PRINT #1,"  8"
        PRINT #1, K
        PRINT #1," 38"
        PRINT #1, Z+Z0
        PRINT #1." 0"
      END IF
      RETURN
      END
```

APPENDIX "C"

DETAILED AIRCRAFT INTERIOR DRAWINGS

FIGURE C.1 - GENERAL INTERIOR - L-1011

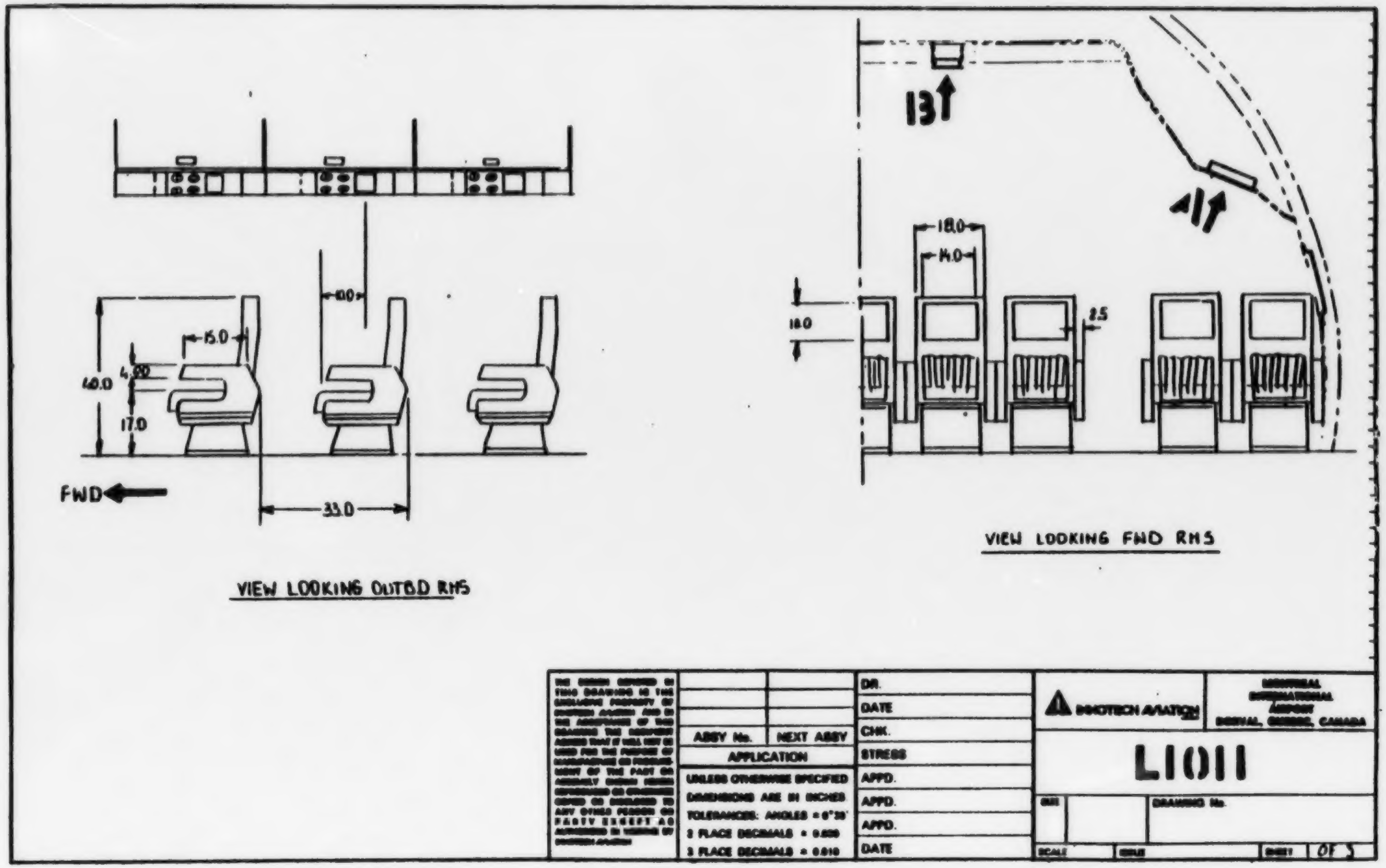


FIGURE C.2 - CENTRE P.S.U. PANEL DETAIL - L-1011

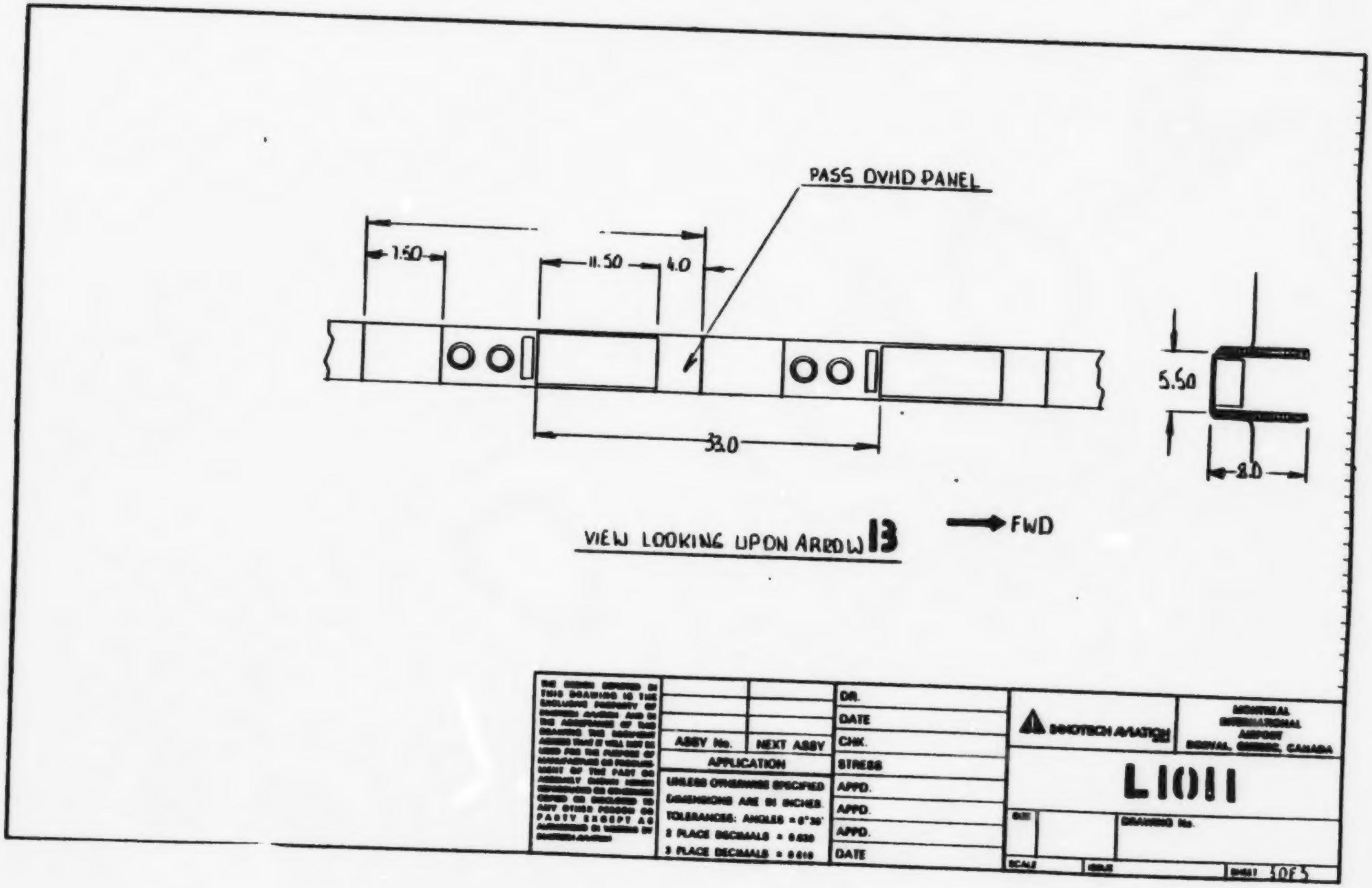


FIGURE C.3 - OUTBOARD P.S.U. PANEL DETAIL - L-1011

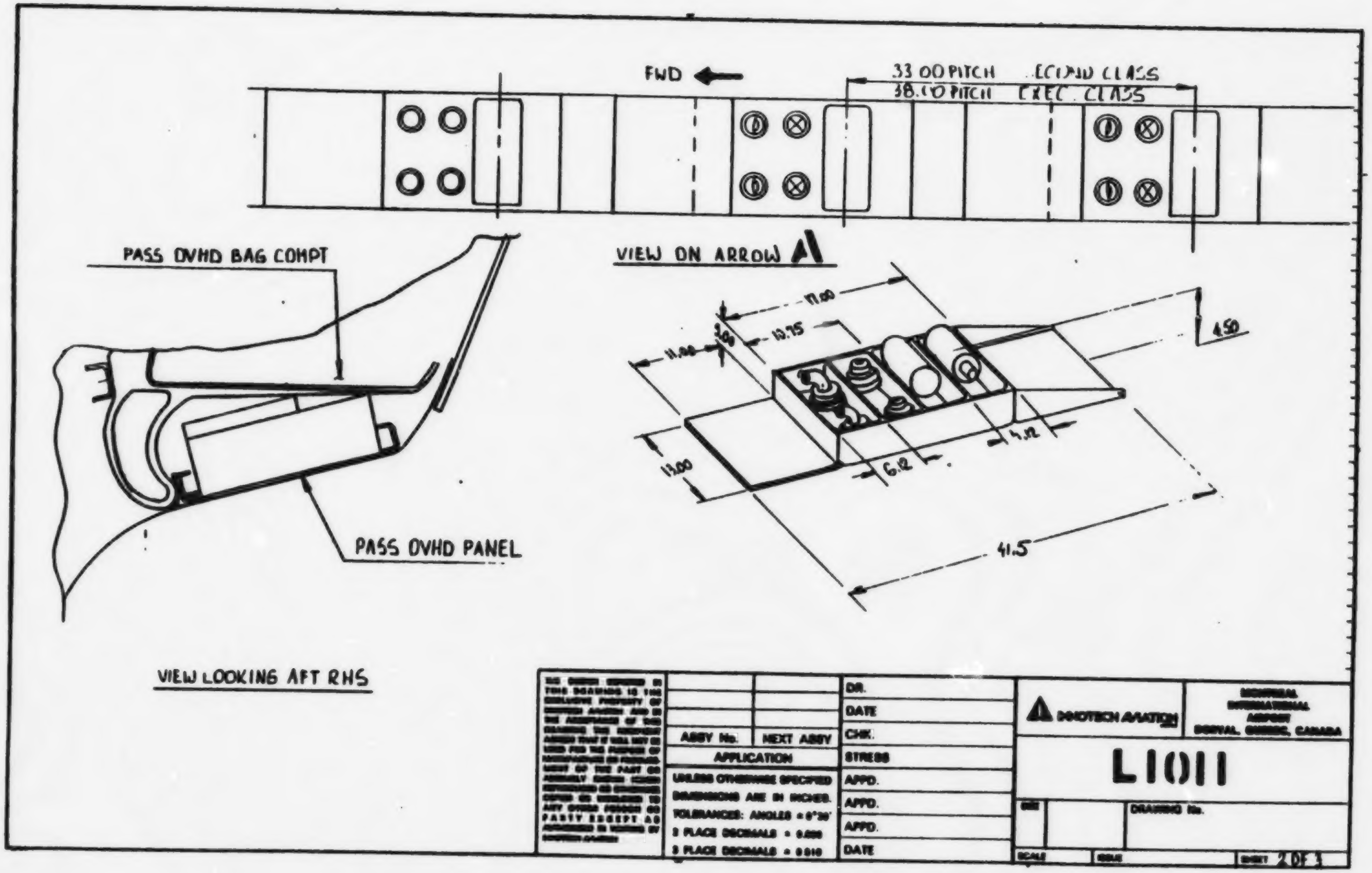


FIGURE C.4 - GENERAL INTERIOR - B-767

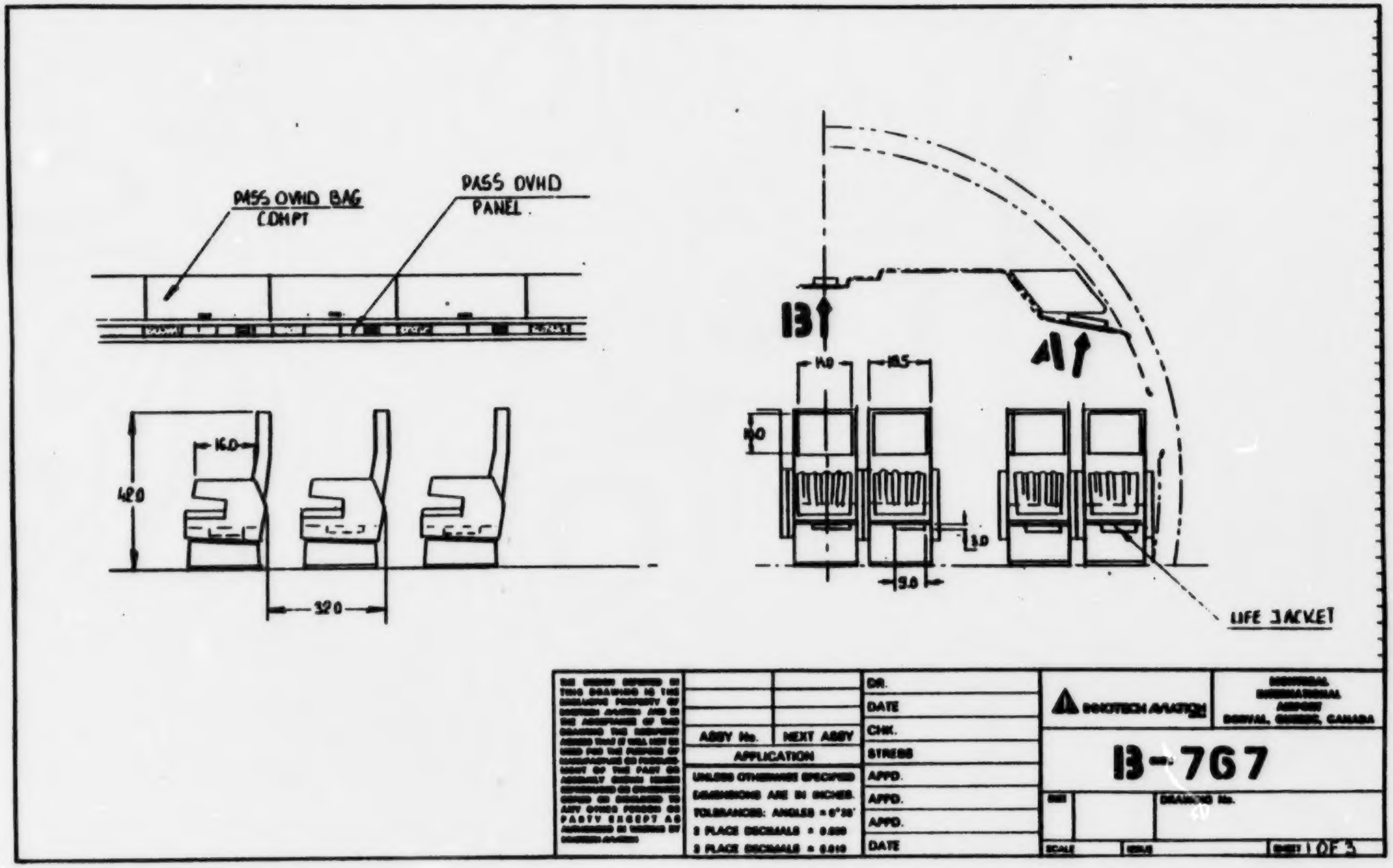


FIGURE C.5 - CENTRE P.S.U. PANEL DETAIL - B-767

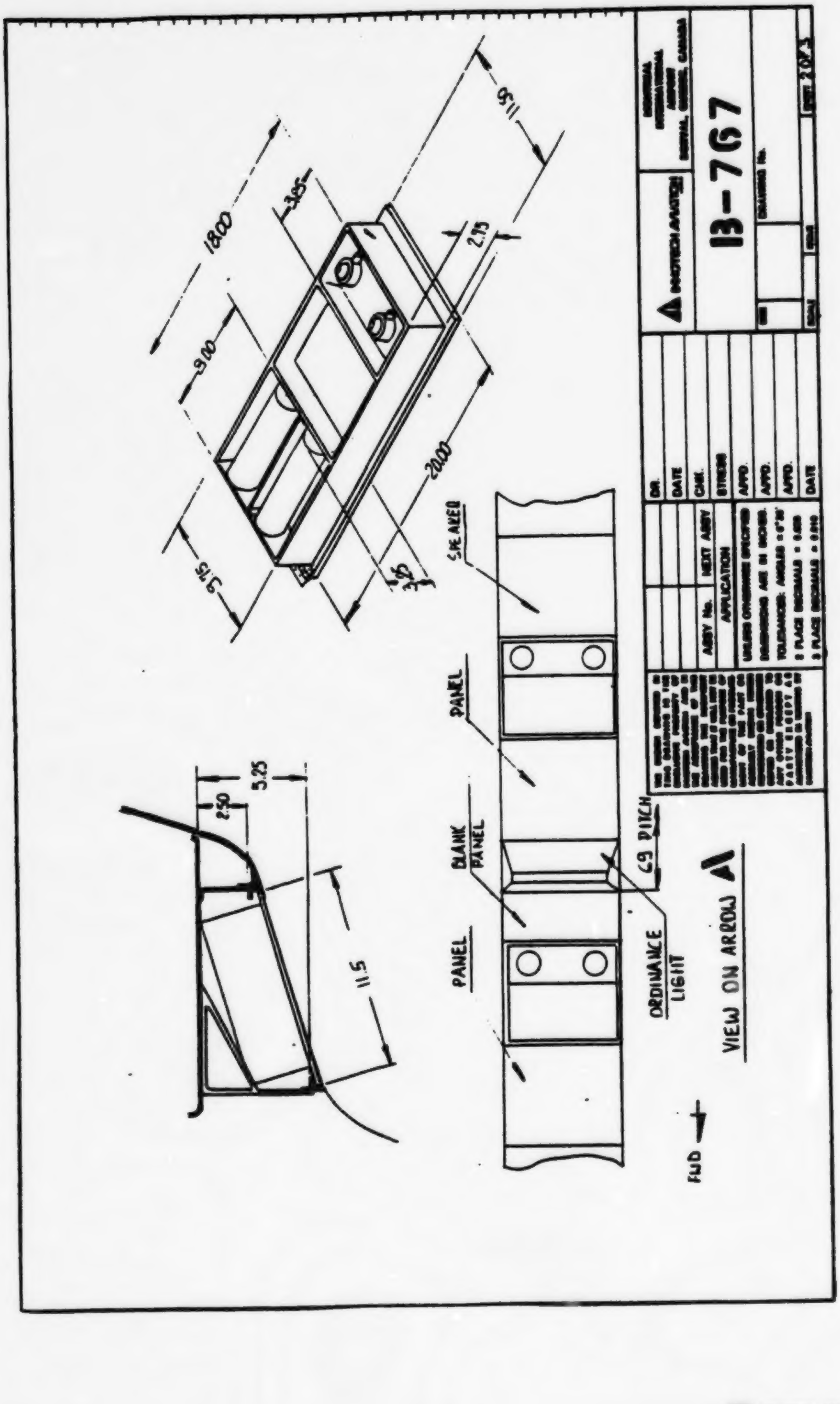


FIGURE C.6 - OUTBOARD P.S.U. PANEL DETAIL - B-767

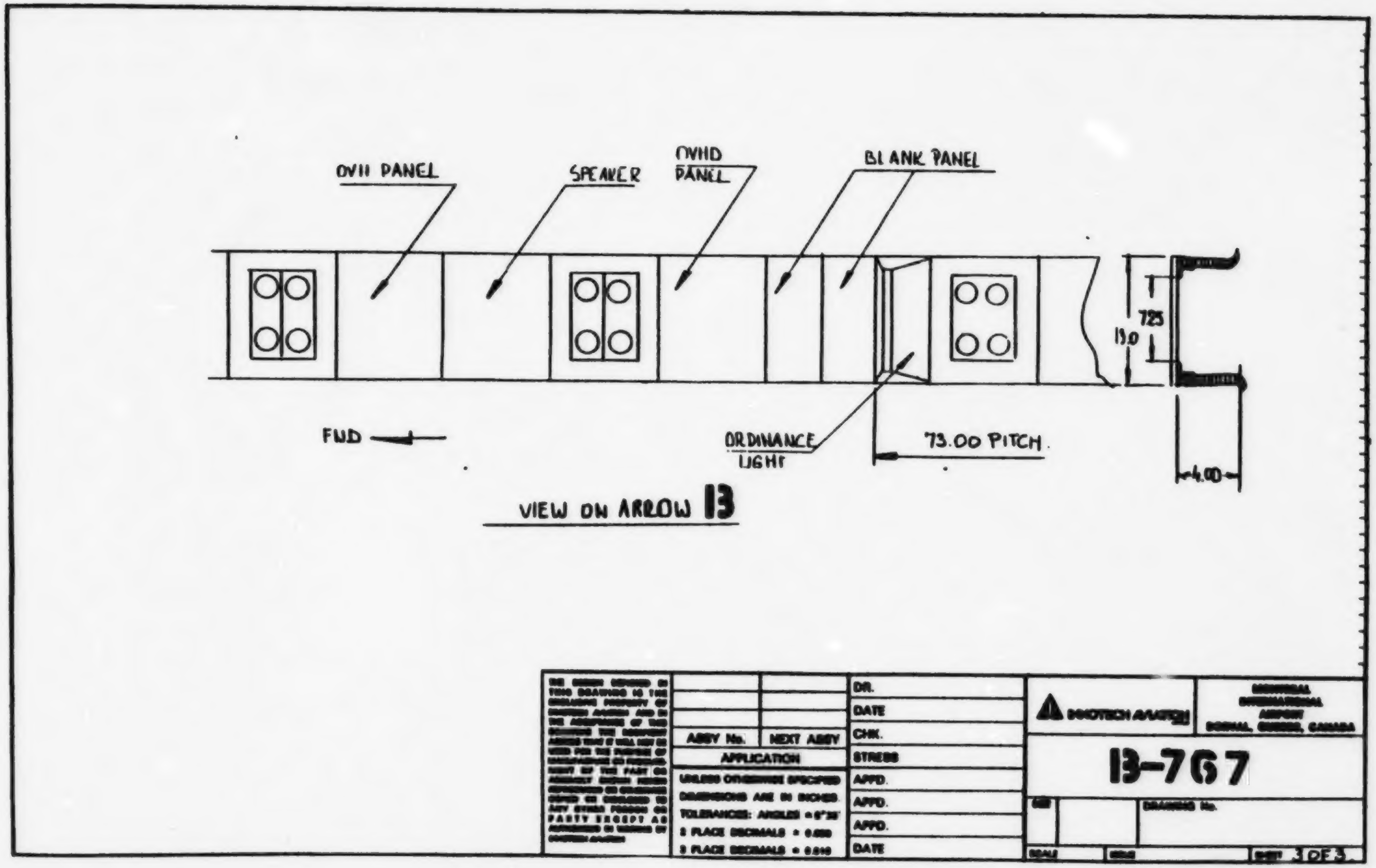


FIGURE C.7 - P.S.U. PANEL DETAIL - B-737

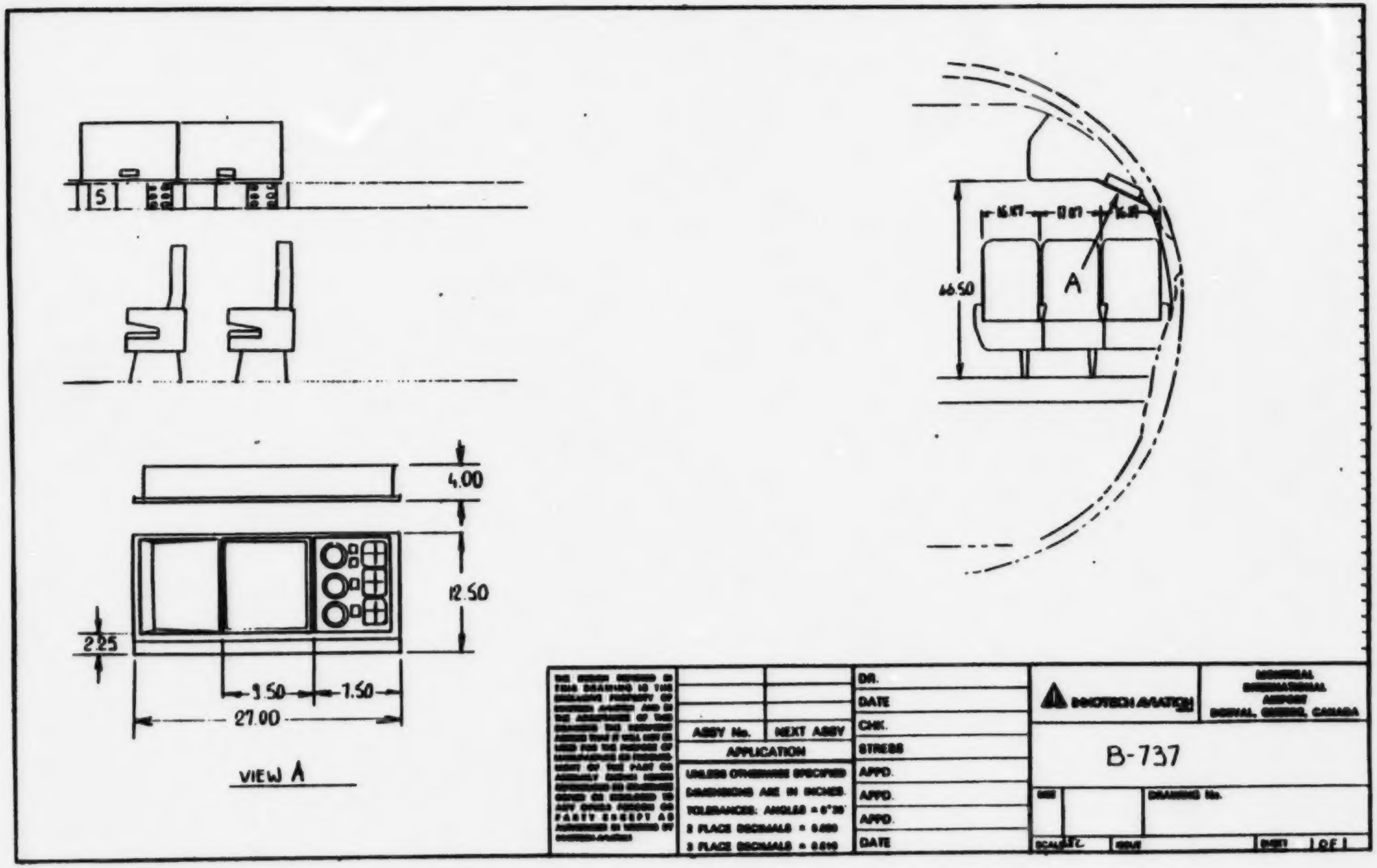
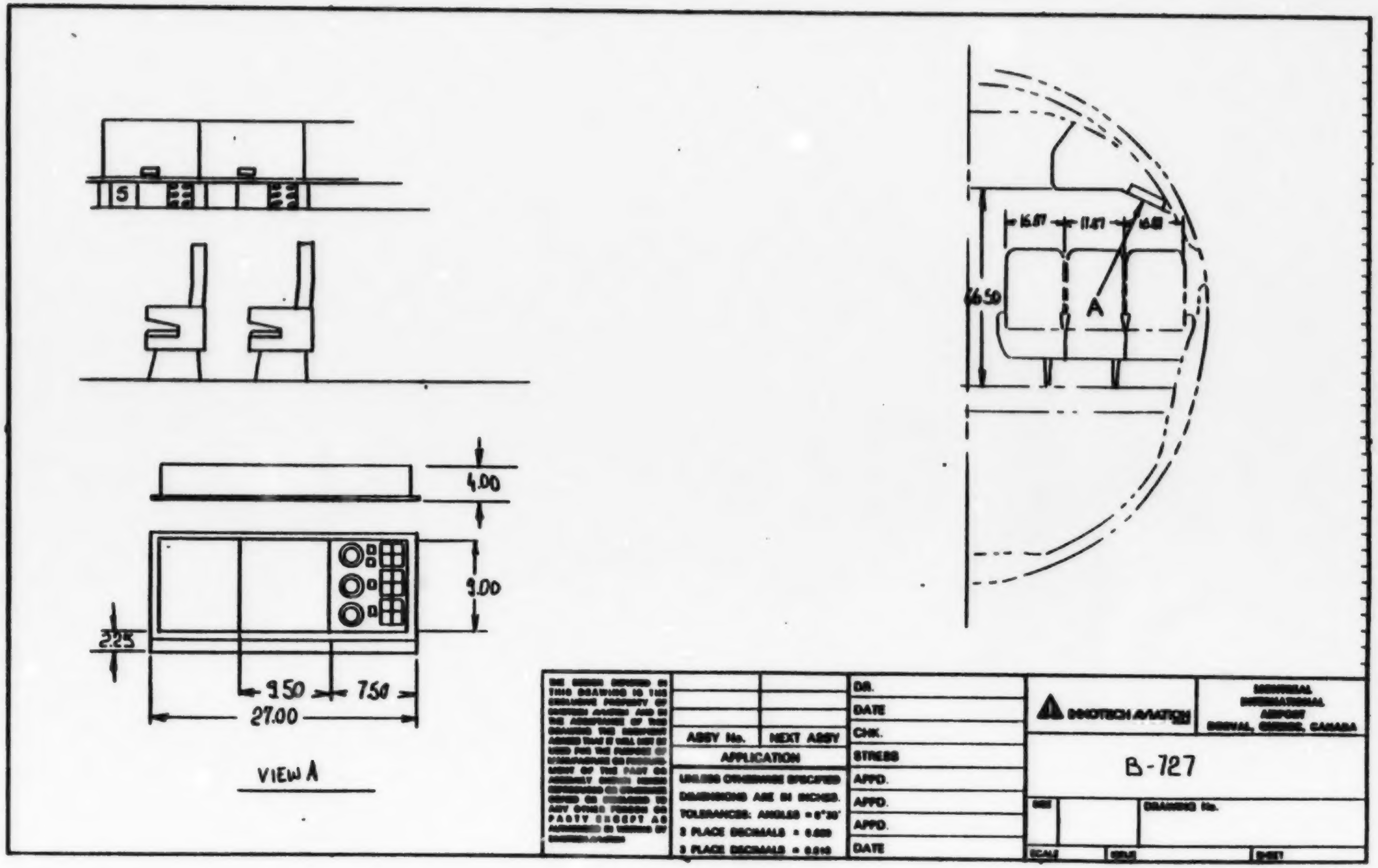


FIGURE C.8 - P.S.U. PANEL DETAIL - B-727



APPENDIX "D"

IMPLEMENTATION COST ANALYSIS

P.P.B.E. IMPEMENTATION COSTING APRIL 88

COSTING PARAMETERS:

ANNUNCIATION SYS. INSTL./MOD	>>>>>	LABOR REQUIRED FOR THE P.P.B.E. OR P.P.B.E./HYPOXIA ANNUNCIATION SYSTEM INSTALLATION AND ASSOCIATED MODIFICATIONS REQUIRED TO THE AIRCRAFT
REMOVAL OF EXISTING EQUIP	>>>>>	LABOR REQUIRED TO REMOVE AND STORE EXISTING SYSTEMS AND SUBSYSTEMS DISPLACED BY THE P.P.B.E.
INSTL OF PSU/PPB EQUIP.	>>>>>	LABOR REQUIRED TO INSTALL P.P.B.E. AND REINSTALL SYSTEMS & MISC. COMPONENTS.
SEAT MODIFICATION	>>>>>	LABOR REQUIRED TO MODIFY SEATS OR SEAT PARTS TO ALLOW INSTALLATION OF P.P.B.E.
INSTL OF PANELS & MISC.	>>>>>	LABOR REQUIRED TO RE-INSTALL AIRCRAFT COMPONENTS SUCH AS P.S.U. PANELS, BAGGAGE BINS, FALSE CEILINGS.
RELOCATION OF MISC.	>>>>	LABOR REQUIRED TO RELOCATE EXISTING COMPONENTS & SYSTEMS.
P.P.B.E. +10%	>>>>>	COST OF P.P.B. UNIT + 10% TO ALLOW FOR THE ADDITIONAL UNITS REQUIRED ON AIRCRAFT. (EXACT P.P.B.E. COST UNKNOWN).
MISC. MOUNT MATERIAL FOR MODS INCL WIRING/CTLS/HARDWARE	>>>>>	CATCH ALL FOR CAPITAL EQUIPMENT COST NOT SPECIFICALLY IDENTIFIED. INCLUDES ADDITIONAL HARDWARE, CONTROLS, SENSORS, CIRCUITRY, WIRING, FABRICS, ETC..
ENGINEERING STUDIES	>>>>>	ALLOWS FOR ENGINEERING SUBJECT STUDIES, SUPPLIER SURVEYS, FEASIBILITY STUDIES, PRELIMINARY DESIGN STUDIES, LIAISON.
ENGINEERING SUPPORT	>>>>>	ALLOWS FOR ENGINEERING DRAWINGS, ANALYSIS, PROJECT PLANNING, COMPLIANCE & CERTIFICATION, IMPACT STUDIES, MANUFACTURING SUPPORT (LIAISON), PURCHASING.
OTHER SUPPORT	>>>>>	PURCHASING, SHIPPING, RECEIVING, HANDLING ETC.

COST PER SEATING POSITION - IMPLEMENTATION - SCHEME DEPENDENT - SELF CONTAINED -

---

SYSTEM/DETAILS	MODIFY LABOR RATES AS REQUIRED ALONG THIS LINE >>>>	MOD.	RATE 48.00 PER HR	ELECT /DIY	RATE 48.00 PER HR	ENGIN.	RATE 58.00 PER HR	QA/OTHER	RATE 48.00 PER HR	TOTAL LABOR COST	TOTAL MATERIAL COST	TOTAL COST

OVERHEAD AUTO
PRESENTATION

ANNUNCIATION SYS. INSTL/MOD	1.00	48.00	1.00	48.00	0.00	58.00	0.20	48.00	105.60		
REMOVAL OF PSU PANEL & EQUIP	1.50	48.00	1.00	48.00	0.00	58.00	0.20	48.00	129.60		
INSTL OF PSU/PPB EQUIP.	3.00	48.00	2.00	48.00	0.00	58.00	0.60	48.00	268.80		
INSTL OF PANELS & MISC	1.50	48.00	2.50	48.00	0.00	58.00	0.40	48.00	211.20		
P.P.B. UNIT + 10%										330.00	
MISC. MOUNT MATERIAL FOR MODS INCL WIRING/CTLS/HARDWARE										650.00	
P.S.U. PANEL CAP. COST										300.00	
ENGINEERING STUDIES					0.50	58.00			29.00		
ENGINEERING SUPPORT					3.00	58.00			174.00		
OTHER SUPPORT							0.50	48.00	24.00		
											2222.20 <<<<<<

OVERHEAD
SELF HELP

ANNUNCIATION	1.00	48.00	1.00	48.00		58.00	0.20	48.00	105.60		
REMOVAL OF PSU PANEL & EQUIP	1.50	48.00	1.00	48.00		58.00	0.20	48.00	129.60		
INSTL OF PSU/PPB EQUIP.	2.00	48.00	1.50	48.00		58.00	0.40	48.00	187.20		
INSTL OF PANELS & MISC.	1.50	48.00	1.50	48.00		58.00	0.40	48.00	163.20		
P.P.B. UNIT + 10%										330.00	
MISC. MOUNT MATERIAL FOR MODS INCL WIRING/CTLS/HARDWARE										300.00	
P.S.U. PANEL CAP. COST										300.00	
ENGINEERING STUDIES					0.50	58.00			29.00		
ENGINEERING SUPPORT					2.50	58.00			145.00		
OTHER SUPPORT							0.50	48.00	24.00		
											1713.60 <<<<<<

SEATBACK
AUTOPRESENTATION — SEATS CONSIDERED REMOVED FOR RE-FURB
AND P.P.B.E. STOWED INSIDE SEAT - ELECT WIRING REQD

ANNUNCIATION	1.00	48.00	1.00	48.00		58.00	0.20	48.00	105.60		
SEAT MODIFICATION	4.00	48.00	1.50	48.00		58.00	0.20	48.00	273.60		
INSTL OF P.P.B.	2.00	48.00	1.50	48.00		58.00	0.20	48.00	177.60		
RELOCATION OF MISC.	2.50	48.00	0.00	48.00		58.00	0.10	48.00	124.80		
ADDED INSTL. COST		48.00	1.00	48.00		58.00	0.10	48.00	52.80		
P.P.B. UNIT + 10%										330.00	
MISC. MOUNT MATERIAL FOR MODS INCL WIRING/CTLS/HARDWARE										550.00	
REPLACEMENT EQUIP. CAP COST										150.00	
ENGINEERING STUDIES					0.50	58.00			29.00		
ENGINEERING SUPPORT					3.00	58.00			174.00		
OTHER SUPPORT							0.50	48.00	24.00		
											1991.40 <<<<<<

SEATBACK

SELF-HELP'A' — SEATS CONSIDERED REMOVED FOR RE-FURB
AND P.P.B.E STOWED INSIDE SEAT

ANNUNCIATION	1.00	48.00	1.00	48.00		58.00	0.20	48.00	105.60		
SEAT MODIFICATION	4.00	48.00	0.00	48.00		58.00	0.20	48.00	201.60		
INSTL OF P.P.B	1.00	48.00	0.50	48.00		58.00	0.20	48.00	81.60		
RELOCATION OF MISC.	2.50	48.00	0.00	48.00		58.00	0.10	48.00	124.80		
ADDED INSTL COST		48.00	1.00	48.00		58.00	0.10	48.00	52.80		
P.P.B. UNIT + 10%										330.00	
MISC. MOUNT MATERIAL FOR MODS INCL WIRING/CTLS/HARDWARE										300.00	
REPLACEMENT EQUIP. CAP COST										150.00	
ENGINEERING STUDIES					0.50	58.00			29.00		
ENGINEERING SUPPORT					2.50	58.00			145.00		
OTHER SUPPORT							0.50	48.00	24.00		
											1544.40 <<<<<<

```
SEATBACK
SELF HELP'B'             SEATS CONSIDERED REMOVED FOR RE-FURB
---------                AND P.P.B.E STOWED ON SEAT


ANNUNCIATION                      1.00   48.00   1.00   48.00          58.00   0.20   48.00        105.60

SEAT MODIFICATION                 2.00   48.00   0.00   48.00          58.00   0.10   48.00        100.80

INSTL OF P.P.B                    0.50   48.00   0.50   48.00          58.00   0.10   48.00         52.80

RELOCATION OF MISC.               1.00   48.00   0.00   48.00          58.00   0.10   48.00         52.80
ADDED INSTL COST                         48.00   1.00   48.00          58.00   0.00   48.00         48.00

P.P.B. UNIT + 10%                                                                                          330.00

MISC. MOUNT MATERIAL FOR MODS




INCL WIRING/CTLS/HARDWARE                                                                                  300.00

REPLACEMENT EQUIP. CAP COST                                                                                150.00


ENGINEERING STUDIES (EVALUATION, IMPL. SCHEMES)                  0.50   58.00                        29.00
ENGINEERING SUPPORT (DRAWINGS, LIAISON, PLANNING, COMPLIANCE)    1.00   58.00                        58.00
                                                                                0.50   48.00         24.00
                                                                                                                      1251.00 <<<<<<
UNDERSEAT
SELF HELP                SEATS CONSIDERED REMOVED FOR RE-FURB
---------                AND P.P.B.E STOWED UNDER ST- ELECT. WIRING REQD


ANNUNCIATION                      1.50   48.00   1.00   48.00          58.00   0.20   48.00        129.60

SEAT MODIFICATION                 0.50   48.00   0.00   48.00          58.00   0.10   48.00         28.80

INSTL OF P.P.B                    1.50   48.00   0.00   48.00          58.00   0.10   48.00         76.80

RELOCATION OF MISC.               1.00   48.00   0.00   48.00          58.00   0.10   48.00         52.80
ADDED INSTL COST                         48.00   1.00   48.00          58.00   0.10   48.00         52.80

P.P.B. UNIT + 10%                                                                                          330.00

MISC. MOUNT MATERIAL FOR MODS
INCL WIRING/CTLS/HARDWARE                                                                                  100.00

REPLACEMENT EQUIP. CAP COST                                                                                100.00


ENGINEERING STUDIES                                              0.50   58.00                        29.00
ENGINEERING SUPPORT                                              1.00   58.00                        58.00
OTHER SUPPORT                                                                   0.50   48.00         24.00
                                                                                                                       981.80 <<<<<<<
```

```
SEAT ARMREST    ASSUMES EXTENSIVE MOD TO ARMREST ASSY
------------

ANNUNCIATION                   1.00   48.00   1.00   48.00           58.00   0.20   48.00        105.60

ARMREST MOD                    4.00   48.00   2.00   48.00           58.00   0.20   48.00        297.60




INSTL OF PPD/EQUIP             2.50   48.00   1.00   48.00           58.00   0.40   48.00        107.20

RELOCATION OF MISC.            2.00   48.00   1.00   48.00           58.00   0.10   48.00        148.80
ADDED INSTL COST                      48.00   0.00   48.00           58.00   0.00   48.00          0.00

P.P.D. UNIT + 10%                                                                                         330.00

ANNUNCIATION & MISC.                                                                                       50.00

ARMREST EQUIP                                                                                             450.00

ENGINEERING STUDIES                                          0.50    58.00                          29.00
ENGINEERING SUPPORT                                          3.00    58.00                         174.00
OTHER SUPPORT                                                                0.50   48.00           24.00
                                                                                                                      1796.20 <<<<<<


SEAT MEALTRAY   ASSUMES NEW MEAL TRAY ASSY REQD
-------------

ANNUNCIATION                   1.00   48.00   1.00   48.00           58.00   0.20   48.00        105.60

REMOVAL/ADDITION  INCL. P.P.D.E.   1.00   48.00   1.00   48.00       58.00   0.10   48.00        100.80

SEAT MOD REQ'D                 1.50   48.00   0.00   48.00           58.00   0.40   48.00         91.20

RELOCATION OF MISC.            0.00   48.00   0.00   48.00           58.00   0.10   48.00          4.80
ADDED INSTL COST                      48.00   0.00   48.00           58.00   0.00   48.00          0.00

P.P.D. UNIT + 10%                                                                                         330.00

ANNUNCIATION & MISC.                                                                                       50.00

MEAL TRAY UNIT                                                                                            350.00

ENGINEERING STUDIES                                          0.50    58.00                          29.00
ENGINEERING SUPPORT                                          3.00    58.00                         174.00
OTHER SUPPORT                                                                0.50   48.00           24.00
                                                                                                                      1259.40 <<<<<<<
```

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CARRY-ON
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ANNUNCIATION                             1.00    48.00     1.00    48.00             58.00     0.20    48.00      105.60

SEAT MODIFICATION                        0.00    48.00     0.00    48.00             58.00     0.00    48.00        0.00

INSTL OF P.P.B                           0.00    48.00     0.00    48.00             58.00     0.00    48.00        0.00

RELOCATION OF MISC.                      0.00    48.00     0.00    48.00             58.00     0.00    48.00        0.00
ADDED INSTL COST                                 48.00     0.00    48.00             58.00     0.00    48.00        0.00

P.P.B. UNIT + 10%                                                                                                             330.00

ANNUNCIATION & MISC.                                                                                                           50.00


ENGINEERING STUDIES                                                        0.50    58.00                               29.00
ENGINEERING SUPPORT                                                        0.50    58.00                               29.00
OTHER SUPPORT                                                                               0.50    48.00              24.00
                                                                                                                                          567.60 <<<<<<
```

COST PER SEATING POSITION - IMPLEMENTATION - SCHEME DEPENDENT - PARTIALLY DEPENDENT ON REMOTE OXYGEN SOURCE

SYSTEM/DETAILS	MODIFY LABOR RATES AS REQUIRED ALONG THIS LINE >>>>	MOD.	RATE 48.00 PER HR	ELECT	RATE 48.00 PER HR	ENGIN.	RATE 58.00 PER HR	QA/OTHER	RATE 48.00 PER HR	TOTAL LABOR COST	TOTAL MATERIAL COST	TOTAL COST
OVERHEAD AUTO PRESENTATION												
ANNUNCIATION SYS. INSTL/MOD		1.00	48.00	1.00	48.00	0.00	58.00	0.20	48.00	105.60		
REMOVAL OF PSU PANEL & EQUIP		1.50	48.00	1.00	48.00	0.00	58.00	0.20	48.00	129.60		
INSTL OF PSU/PPB EQUIP.		3.50	48.00	3.00	48.00	0.00	58.00	0.80	48.00	350.40		
INSTL OF PANELS & MISC		1.50	48.00	3.00	48.00	0.00	58.00	0.50	48.00	240.00		
P.P.B. UNIT + 10%											330.00	
MISC. MOUNT MATERIAL FOR MODS INCL WIRING/CTLS/HARDWARE											650.00	
P.S.U. PANEL CAP. COST											300.00	
ENGINEERING STUDIES						0.50	58.00			29.00		
ENGINEERING SUPPORT						3.00	58.00			174.00		
OTHER SUPPORT								0.50	48.00	24.00		
												2332.60 <<<<<<

```
OVERHEAD
SELF HELP
---------

ANNUNCIATION                   1.00   48.00   1.00   48.00          58.00   0.20   48.00      105.60

REMOVAL OF PSU PANEL & EQUIP   1.50   48.00   1.00   48.00          58.00   0.20   48.00      129.

INSTL OF PSU/PPB EQUIP.        2.50   48.00   2.00   48.00          58.00   0.60   48.00      244.80

INSTL OF PANELS  & MISC.       1.50   48.00   2.00   48.00          58.00   0.60   48.00      19

P.P.B. UNIT + 10%                                                                                     330.00

MISC. MOUNT MATERIAL FOR MODS
INCL WIRING/CTLS/HARDWARE                                                                             300.00

P.S.U. PANEL CAP. COST                                                                                300.


ENGINEERING STUDIES                                          0.50   58.00                       29.00
ENGINEERING SUPPORT                                          2.50   58.00                      145.0
OTHER SUPPORT                                                               0.50   48.00        24.00
                                                                                                               1804.80 <<<<<<

SEATBACK
AUTOPRESENTATION        SEATS CONSIDERED REMOVED FOR RE-FURB
----------------        AND P.P.B.E. STOWED INSIDE SEAT - ELECT WIRING REQ


ANNUNCIATION                   1.00   48.00   1.00   48.00          58.00   0.20   48.00      105.60

SEAT MODIFICATION              4.50   48.00   2.00   48.00          58.00   0.20   48.00      321.

INSTL OF P.P.B.                2.50   48.00   2.00   48.00          58.00   0.40   48.00      235.20

RELOCATION OF MISC.            2.50   48.00   0.00   48.00          58.00   0.20   48.00      129.60
ADDED INSTL. COST                     48.00   1.00   48.00          58.00   0.10   48.00       52.80

P.P.B. UNIT + 10%                                                                                     330.00

MISC. MOUNT MATERIAL FOR MODS
INCL WIRING/CTLS/HARDWARE                                                                             550.00



REPLACEMENT EQUIP. CAP COST                                                                           150.00

ENGINEERING STUDIES                                          0.50   58.00                       29.00
ENGINEERING SUPPORT                                          3.00   58.00                      174.00
OTHER SUPPORT                                                               0.50   48.00        24.00
                                                                                                               2101.80 <<<<<<
```

```
SEATBACK
SELF HELP'A'          SEATS CONSIDERED REMOVED FOR RE-FURB
---------             AND P.P.D.E STOWED INSIDE SEAT - ELECT WIRING REQ'D


ANNUNCIATION                   1.00   48.00   1.00   48.00          58.00   0.20   48.00        105.60

SEAT MODIFICATION              4.50   48.00   1.00   48.00          58.00   0.20   48.00        273.60

INSTL OF P.P.D                 1.50   48.00   1.00   48.00          58.00   0.40   48.00        139.20

RELOCATION OF MISC.            2.50   48.00   0.00   48.00          58.00   0.10   48.00        124.80
ADDED INSTL COST                      48.00   1.00   48.00          58.00   0.10   48.00         52.80

P.P.D. UNIT + 10%                                                                                        330.00

MISC. MOUNT MATERIAL FOR MODS
INCL WIRING/CTLS/HARDWARE                                                                                300.00

REPLACEMENT EQUIP. CAP COST                                                                              150.00


ENGINEERING STUDIES                                           0.50   58.00                        29.00
ENGINEERING SUPPORT                                           2.50   58.00                       145.00
OTHER SUPPORT                                                               0.50   48.00          24.00
                                                                                                                  1674.00 <<<<<<


SEATBACK
SELF HELP'B'          SEATS CONSIDERED REMOVED FOR RE-FURB
---------             AND P.P.D.E STOWED ON SEAT - ELECT. WIRING REQD


ANNUNCIATION                   1.00   48.00   1.00   48.00          58.00   0.20   48.00        105.60



SEAT MODIFICATION              2.00   48.00   1.00   48.00          58.00   0.10   48.00        148.80

INSTL OF P.P.D                 1.00   48.00   1.00   48.00          58.00   0.40   48.00        115.20

RELOCATION OF MISC.            1.00   48.00   0.00   48.00          58.00   0.10   48.00         52.80
ADDED INSTL COST                      48.00   1.00   48.00          58.00   0.10   48.00         52.80

P.P.D. UNIT + 10%                                                                                        330.00

MISC. MOUNT MATERIAL FOR MODS
INCL WIRING/CTLS/HARDWARE                                                                                300.00

REPLACEMENT EQUIP. CAP COST                                                                              150.00

ENGINEERING STUDIES                                           0.50   58.00                        29.00
ENGINEERING SUPPORT                                           1.00   58.00                        58.00
OTHER SUPPORT                                                               0.50   48.00          24.00
                                                                                                                  1366.20 <<<<<<
```

UNDERSEAT
SELF HELP

SEATS CONSIDERED REMOVED FOR RE-FURB
AND P.P.D.E STOWED UNDER ST- ELECT. WIRING REQD

ANNUNCIATION	1.50	48.00	1.00	48.00		58.00	0.20	48.00	129.60		
SEAT MODIFICATION	0.50	48.00	1.00	48.00		58.00	0.10	48.00	76.80		
INSTL OF P.P.D	1.50	48.00	1.00	48.00		58.00	0.40	48.00	139.20		
RELOCATION OF MISC.	1.00	48.00	0.00	48.00		58.00	0.10	48.00	52.80		
ADDED INSTL COST		48.00	1.00	48.00		58.00	0.10	48.00	52.80		
P.P.D. UNIT + 10%										330.00	
MISC. MOUNT MATERIAL FOR MODS INCL WIRING/CTLS/HARDWARE										100.00	
REPLACEMENT EQUIP. CAP COST										100.00	
ENGINEERING STUDIES					0.50	58.00			29.00		
ENGINEERING SUPPORT					1.00	58.00			58.00		
OTHER SUPPORT							0.50	48.00	24.00		
											1092.20 <<<<<<<

SEAT ARMREST   ASSUMES EXTENSIVE MOD TO ARMREST ASSY

ANNUNCIATION	1.00	48.00	1.00	48.00		58.00	0.20	48.00	105.60		
ARMREST MOD	4.00	48.00	2.00	48.00		58.00	0.20	48.00	297.60		
INSTL OF PPD/EQUIP	2.50	48.00	1.00	48.00		58.00	0.40	48.00	187.20		
RELOCATION OF MISC.	2.00	48.00	1.00	48.00		58.00	0.10	48.00	148.80		
ADDED INSTL COST	3.00	48.00	1.50	48.00		58.00	0.40	48.00	235.20		
P.P.D. UNIT + 10%										330.00	
ANNUNCIATION & MISC.										50.00	
ARMREST EQUIP										450.00	
ENGINEERING STUDIES					0.50	58.00			29.00		
ENGINEERING SUPPORT					3.00	58.00			174.00		
OTHER SUPPORT							0.50	48.00	24.00		
											2031.40 <<<<<<

```
SEAT MEALTRAY    ASSUMES NEW MEAL TRAY ASSY REQD
-------------

ANNUNCIATION                     1.00   48.00   1.00   48.00           58.00   0.20   48.00      105.60

REMOVAL/ADDITION  INCL. P.P.B.E. 1.00   48.00   1.00   48.00           58.00   0.10   48.00      100.80

SEAT MOD REQ'D                   3.00   48.00   1.00   48.00           58.00   0.60   48.00      220.80

RELOCATION OF MISC.              0.00   48.00   0.00   48.00           58.00   0.10   48.00        4.80
ADDED INSTL COST                        48.00   0.00   48.00           58.00   0.00   48.00        0.00

P.P.B. UNIT + 10%                                                                                         330.00

ANNUNCIATION & MISC.                                                                                       50.00




MEAL TRAY UNIT                                                                                            350.00

ENGINEERING STUDIES                                             0.50   58.00                       29.00
ENGINEERING SUPPORT                                             3.00   58.00                      174.00
OTHER SUPPORT                                                                 0.50   48.00         24.00
                                                                                                                   1389.00 <<<<<<<


SMOKE/HYPOXIA
OVERHEAD AUTO
PRESENTATION
-------------


ANNUNCIATION                     1.00   48.00   1.00   48.00           58.00   0.20   48.00      105.60

REMOVAL OF PSU PANEL & EQUIP     1.50   48.00   2.00   48.00           58.00   0.20   48.00      177.60

INSTL OF PSU EQUIP               2.50   48.00   3.00   48.00           58.00   0.80   48.00      302.40

INSTL OF PANELS   & MISC         1.50   48.00   3.00   48.00           58.00   0.50   48.00      240.00


P.P.B. UNIT + 10%                                                                                         400.00

MISC. MOUNT MATERIAL FOR MODS
INCL WIRING/CTLS/HARDWARE                                                                                 650.00

P.S.U. PANEL CAP. COST                                                                                    300.00

ENGINEERING STUDIES                                             0.50   58.00                       29.00
ENGINEERING SUPPORT                                             3.00   58.00                      174.00
OTHER SUPPORT                                                                 0.50   48.00         24.00
                                                                                                                   2402.60 <<<<<<<
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APPENDIX "E"

BINARY DECISION ANALYSIS
TECHNIQUE AND SAMPLE COMPUTATION

BINARY DECISION ANALYSIS TECHNIQUE

Step 1 Identify the Important "Decision Criteria" or "Decision Variables"

This involves simply enumerating the factors, both quantitative and qualitative, which should be considered in selecting a stowage/presentation concept from the perspective of a decision maker faced with a major capital expenditure. An effort is made to keep this list as short as possible without excluding any important variables, and to minimize the "double-counting" or duplication of variables. In other words, the criteria selected must be mutually exclusive and collectively exhaustive.

Step 2 Weighting the Decision Criteria

Having identified the major decision criteria, it is necessary to attach relative weights to each criterion, as they are not all equally important to the selection process. APS' binary decision analysis technique was used to establish the relative weights of the decision criteria.

The technique requires examining every possible pair of criteria, deciding which of the two criteria is the most important, and then assigning a 1 to the most important and 0 to the less important criterion. After every pair is evaluated the number of 1's received by each criterion is calculated to produce a "raw" total score. The highest scoring criterion is the most important. A simple mathematical transformation(1) is then performed to convert the raw scores into percentage weights or scores. A relative ranking can be assigned based on the percentage scores.

---

(1) Unity is first added to every raw score to ensure no zero scores are present and then each score is converted into a percentage figure.

Step 3 **Evaluating Each Stowage/Presentation Concept Using the Decision Criteria**

This step involves an assessment of each stowage/presentation scheme, to establish a ranking on the basis of ability to satisfy the criterion being considered. Again a binary decision analysis process is used. It involves examining the concepts in pairs, deciding which of the two concepts best meets the criterion being considered, and then assigning a 1 to the preferred type, and 0 to the less desirable type. After every pair of concept has been systematically analysed in this manner, a total is computed. The stowage/presentation concepts with the highest score on a particular criterion is considered the best in fulfilling the demands of that criterion.

Step 4 **Applying the Criteria Weights to the Evaluation Scores to Produce a Final Weighted Score for each Concept**

In the previous step each concept was evaluated on the basis of its ability to satisfy the criterion being considered without any regard for the relative importance or weight of the criterion. In the unweighted form, each criterion has equal value. For example, installation cost is assumed to be just as important as inspection. Therefore, it is now necessary to weight each concept's score by the applicable criterion weight, so that the relative importance of each criterion can be incorporated. This is accomplished by multiplying the relative weights assigned to each of the criteria, by the scores assigned to each stowage/presentation concept for each criterion. This process produces a weighted score of each concept for each criterion considered. The total weighted score for each concept is calculated by adding up the criteria weighted scores associated with a particular aircraft, and normalizing to unity.

It should be noted that the use of the binary decision analysis technique in this application requires such a large number of individual decisions to be made that any subjective biasing of the results by the analysis is highly improbable.

SAMPLE COMPUTATION OF BINARY ANALYSIS

Suppose there are three criteria (A, B, C)
and two alternatives (X, Y)

1) Weighting of Criteria

Criteria	Raw Score			Total Score	Transformed Score	Criteria Weight
A	1	1		2	3	50%
B	0		0	0	1	17%
C		0	1	1	2	33%
				3	6	100%

NOTES:
- "A" is better than "B"
- "A" is better than "C"
- "C" is better than "B"
- Total Score is sum of Raw Scores
- Transformed Score is Total Score plus 1
- Weight is equal to $\frac{\text{Transformed Score}}{\text{Total Transformed Score}}$

2) Evaluation of Alternatives Using Criteria

a) For Criteria "A"

Alternative	Raw Score	Total Score	Transformed Score	Criteria Weight
X	1	1	2	67%
Y	0	0	1	33%
		1	3	100%

NOTES: - For Criteria "A", X is better than "Y"

b) For Criteria "B"

Alternative	Raw Score	Total Score	Transformed Score	Criteria Weight
X	0	0	1	33%
Y	1	1	2	67%
		1	3	100%

c) For Criteria "C"

Alternative	Raw Score	Total Score	Transformed Score	Criteria Weight
X	1	1	2	67%
Y	0	0	1	33%
		1	3	100%

3) Final Scores & Ranking

Alternatives	Score Per Criteria			Total Score
	A	B	C	
X	33.5	5.6	22.1	61.2
Y	16.5	11.4	10.9	38.8
				100.0

NOTE: - Cell "XA" = Criteria Weight "A" multiplied by
Alternative "X" for Criteria "A" divided by 100
= 50 multiplied by 67 divided by 100
Therefore, cell "XA" = 33.5